THE GLACIAL SEQUENCE IN THE MIDDLE MARUIA VALLEY, SOUTH-EAST NELSON, N.Z.

With one separate map in back pocket.

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Science in Geography
in the
University of Canterbury

by

M.C.G. Mabin

University of Canterbury

1976

With one
separate
map in
back pocket

Frontispiece. "Cannibal Gorge". The Right Hand Branch of the Upper Maruia River, looking towards the Lewis Pass which is to the left of the clearing in forest in the distance. The Maruia River flows west under Mt. Technical - the peak on centre skyline. The Lewis Valley branches off to the left from the Lewis Pass.

CONTENTS

LIST OF FIGURES AND TABLES

ACKNOWLEDGEMENTS

Professor Jane Soons supervised this thesis. Her assistance in the field and in the preparation of the text was greatly appreciated.

I would like to thank Dave Glasson, who printed the photographs, and Tony Shatford who helped to solve the problems I encountered in draughting the maps.

Thanks also to the people of the Maruia Valley especially Eric and Eunice Timpson, and John and Elaine Hewison who provided me with accommodation and entertainment during the time I spent in the field.

Finally, thanks to Mrs Ladanyi who typed the manuscript.

ABSTRACT

The glacial and fluvioglacial deposits preserved in the Middle Maruia Valley record the advances and retreats of the Maruia glacier during and since the Otira Glaciation. From the spatial distribution of the various moraines and outwash surfaces five major Otiran advances, and one minor Postglacial advance, are recognised. These are, from oldest to youngest, the Creighton I, II, III Advances, the Reid Stream I, II Advances, and the Springs Advance. There was an interstadial interval between the Creighton III and Reid Stream I advances. A radiocarbon date obtained by Suggate (1965) would suggest that the climax of the Reid Stream I Advance occurred shortly after 14,800 yrs B.P. Prior to several of the advances lakes became impounded in the valley. The largest of these, Lake Maruia, extended more than 15 km upvalley from the Creighton I moraine loop. It existed during the Creighton-Reid Stream Interstadial. The Maruia Otira Glacial Chronology can be correlated reasonably well with the Waiau and Waimakariri glacial sequences. However, a good correlation cannot be made with the standard N.Z. sequence, thus a revised New Zealand Otiran Glacial Chronology is proposed.

CHAPTER I.

INTRODUCTION

For over a century the notion of the Pleistocene Glaciation of parts of the South Island of New Zealand has been accepted. However it is only in the last 20 years that the concept of multiple Late Pleistocene Glaciations has become current in New Zealand. Deposits relating to these Late Pleistocene Glaciations are abundantly preserved in many of the alpine valleys in the South Island. This thesis is an attempt to describe the glacial history of part of the Maruia River Valley, a major tributary of the Buller River, one of the largest rivers to flow west from the Southern Alps.

I. LOCATION AND BOUNDARIES OF STUDY AREA.

The area studied and mapped encompasses that portion of the Maruia River Valley between Maruia Springs (grid ref. S46/751965 * and the mouth of the Warwick River (grid ref. S39/636307) 40 km downvalley (Fig. 1).
South-west of Springs Junction (grid ref. S39/615019) is an area of low relief. The parts of this area whose drainage flows into the Maruia Valley have also been studied. Of principal interest were the gravel

* Grid reference based on the national thousand-yard grid of the 1:63360 topographical map series (NZMS I)

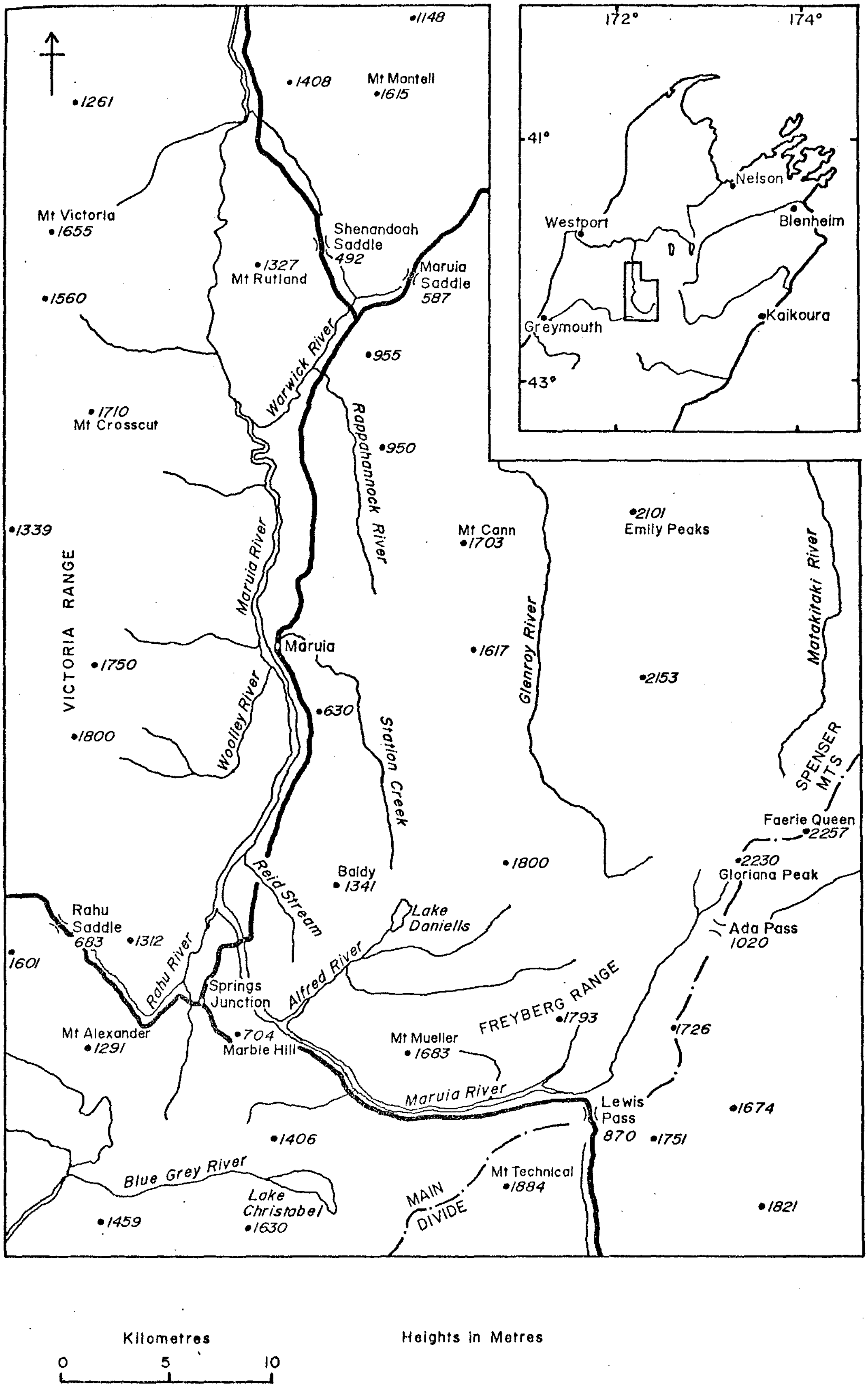

Fig. 1 Location Map.

deposits, thus mapping has been confined largely to the valley floors.

The boundaries of the study area were not chosen arbitrarily. The southern, upstream boundary at Maruia Springs marks the limit of preserved glacial deposits in the Maruia Valley. Upstream of Maruia Springs the valley floor is so narrow that the floodplain occupies its whole width. Therefore extensive glacial deposits have not been preserved. The northern, downstream boundary lies at the upstream mouth of a gorge. This gorge has created a type of sediment trap. No outwash surfaces can be traced through it. However downstream of the gorge several terrace levels are discontinuously preserved. These have not been studied.

II. PREVIOUS WORK

Henderson (1931) summarized the extent of ice in the Maruia Valley in a very general way. He mapped the limits of a large glacier and mentioned the forward moraine loop near the junction of the Maruia and Warwick rivers.

Bowen (1964) mapped some of the deposits which will be discussed herein. He mapped all the deposits as the Speargrass Formation, which was correlated with the Otiran Glacial Stage. This correlation has been maintained.

The Maruia glacial sequence was described in a little more detail by Suggate (1965 pp 37-40). The study had been carried out at a reconnaissance level as an adjunct to the N.Z. Geological Survey's 1:250,000 mapping programme (Suggate 1965 p 12). Four advances in two groups were recognised, and a radiocarbon date was also obtained.

The present work seeks to extend the above, by presenting a detailed description of the glacial sequence in the Middle Maruia Valley.

III. RATIONALE FOR THE STUDY.

In the North Westland and South West Nelson areas only three glacial sequences have been described in any detail; Grey and Taramakau Valleys (Suggate 1965), Lower Inangahua Valley (Nathan and Moar 1973), and the Upper Buller and Motupiko valleys (Adamson 1964). The Maruia Valley sequence is in close proximity to all the above, thus reasonable and interesting correlations with these sequences appeared possible.

Suggate's (1965) chronology of Late Pleistocene Glaciations in the Northern part of the South Island was based on the Grey-Taramakau sequence. Although this chronology has become widely accepted it has its critics. (Soons 1966, Gage 1971). It was hoped that the description and subsequent correlation of the Maruia Valley glacial sequence might help to resolve some of these problems.

The solid geology of the region has been intensively studied by members of the University of Canterbury Geology Department. Adamson (1966) and Stewart (1972) have mapped the northern part of the region. Queck (1976) and Farmer (1967) have mapped in detail the southern part, while Cutten (1976) has mapped the part which forms the eastern flank of the present study area. Mr A. Tullock of the University of Otago Geology Department is presently engaged in mapping the Victoria Range. Therefore, as extensive glacial, and fluvio-glacial deposits were known to exist in the Maruia Valley, the mapping of them was seen as a rounding off of this previous work.

IV. METHODS AND PROBLEMS

Field work was carried out during the months of January, February and March 1976, using the standard geologic mapping techniques and equipment. Mapping was facilitated by extensive use of aerial photographs. These photographs, obtained from N.Z. Aerial Mapping Ltd., were from a super wide angle series taken at a height of 25,000 ft. The photos used were from runs 4033 (29-39), 4034 (46-52) and 4035 (20-26). Also referred to were; the Lands and Survey Department maps, NZMS 1: S39 (Maruia), S46 (Lewis); N.Z. Geological Survey Sheet 15 (Buller), and Miscellaneous Series Map 6 (Quaternary Geology-South Island).

The elevations for the profiles (Fig. 8) were obtained from the NZMS 1 sheets, supplemented by aneroid barometer observations, and computations from the aerial photographs.

While the study was essentially a type of geological mapping, no attempt was made to define new formations, as was done by Suggate (1965). Such a process is considered inappropriate for a glacial sequence. Glacial and fluvio-glacial deposits of the same age are often discontinuously preserved, and of widely differing lithologic character. Clearly the least useful criteria for correlating these types of deposit is their lithology. It is on lithologic grounds that formations are defined. Therefore the glacial sequence has not been mapped in formations, rather the various deposits relating to each advance of the Maruia glacier have been mapped together.

The area mapped follows the valley floor, so is long and narrow. However this was not a drawback as the area is well served by roads. State Highway 7, and Provincial State Highway 65 pass through the area. Five public, and two forestry roads branch off these two main routes.

In pre-European times the area was almost completely covered by beech forest. However much of this has now been cleared, especially on the valley floor. Some forest still remains on the lower slopes of the Victoria Range, particularly south of Maruia (S39/652197). In this and other forested parts mapping was almost impossible. Recent work to realign and seal Provincial State Highway 65 on the eastern valley side has created many fresh road cuttings which have proved invaluable in ellucidating the valley's glacial history.

CHAPTER II.

GEOMORPHIC AND GEOLOGIC BACKGROUND

I. INTRODUCTION TO THE GEOMORPHOLOGY

The Maruia River Valley can be divided into four sectors: Upper, Middle, Gorge and Lower. This division will facilitate the following discussion. It is based on the similarity of physical features within each sector.

The Maruia River flows from a series of tarns 1700 m up on the southern flanks of Gloriana Peak (2215 m) (grid ref. S46/891099). The river flows south-east for 16 km. to the Lewis Pass (grid ref. S46/812963 where it is joined by the Kiwi Stream*. The river then turns to flow east for 24 km. In this stretch it is joined by the Left Branch, Jack Creek, and Alfred rivers. This 40 km section constitutes the Upper Maruia Valley. It is characterised by its steep sides and narrow valley floor.

Emerging from the mountains into its broad Middle sector the Maruia River flows through a small gorge known as the Sluice Box. (Fig. 2) (grid ref. S46/652007).

* Local name. Not a recognised Geographic Board name.

Fig. 2. The Sluice Box.

In its 32 km Middle Sector the river is joined by several major tributaries. From the western flanks of the Victoria Range flow the Rahu and Woolley rivers, and Mitchell Creek. From the lower hills to the east of the Maruia Valley flow Reid Stream, Station Creek, Deep Gully Creek, and the Warwick River.

Downstream of the Maruia-Warwick River junction the river enters a gorge. This sector is 16 km long. Below this it flows northwards for a further 32 km before joining the Buller River. This is the Lower Sector of the Maruia River. While it is wider than the Gorge Sector it nowhere attains the width of the Middle Sector.

Whilst the Sluice Box clearly separates the Upper and Middle Sectors of the Maruia Valley, the separation of the latter from the Upper Grey Valley is not so clear. A low lying depression 3 km wide and 8 km long separates the two valleys. A ridge which rises to 580 m a.s.l. runs down this depression. Between this ridge and the Victoria Range is a low lying area 3.5 km long and 1.2 km wide which is drained by the Rahu River. This area will be referred to as the Rahu Flats. It rises to about 480 m a.s.l. (grid ref. S46/586492). South from this point the drainage joins the Upper Grey River. Between the ridge and the mountains to the east is a swampy low lying region 5 km long and 1.5 km wide. It is drained by Black Stream, which joins the Rahu River. This region will be referred to as the Black Stream Flats. It rises to 489 m a.s.l. at the Mary Maruia Saddle (grid ref. S46/590954). South from the Saddle drainage joins the Upper Grey River.

II. THE GEOLOGIC SETTING.

This survey of the geology of the Maruia-Springs Junction area has been derived mainly from Bowen (1964). More recent mapping has been carried out by Adamson (1966), Farmer (1967), Stewart (1972), Queck (1976) and Cutten (1976) as detailed above.

The geology of the region is varied and complex. Movement along the Alpine Fault has juxtaposed rocks of widely differing composition, structure and genesis. Five major elements can be recognised: The Victoria Range Granites, the Haast Schists and Torlesse Supergroup of the

Spenser Mountains, a complex of ultramafic rocks and volcanoclastic sediments, Lower Paleozoic sediments, and Late Cainozoic sediments. (Fig. 3).

To the west are the Victoria Range Granites. These rocks form a southern extension of the huge north-south trending Karamea Batholith. They were emplaced during Lower Devonian-Carboniferous times. (Cooper 1975).

To the east are the steeply dipping, northeast-southwest trending rocks derived from the New Zealand Geosyncline. (Fleming 1970). The greywackes of the Torlesse Supergroup grade westwards into the schists of the Haast Schist Group. The western margin of these schists is infaulted against a triangular shaped body of rocks of the Maitai and Lee River Groups, and the Rotoroa Igneous Complex. These rocks which are mainly volcanoclastic sediments, diorite and dunite, are also derived from the New Zealand Geosyncline (Grindley 1974). However they were deposited in a vastly different environment to the Haast Schists and Torlesse Greywackes. It is subsequent crustal movements associated with the Alpine Fault which have brought these two terrains into close proximity. (Blake et.al. (1974). Both groups are of Permo-Triassic Age.

Between these granites and geosynclinal deposits outcrop two widely differing sequences. To the south is a succession of Cambrian-Silurian greywackes, limestones, and marbles. These rocks strike northeast-southwest, and have been folded into an anticline about the same axis. To the north is a sequence of Upper Miocene-Late Pleistocene non-marine conglomerates known as the Rappahannock Group. (Cutten 1976). This sequence has been folded into a

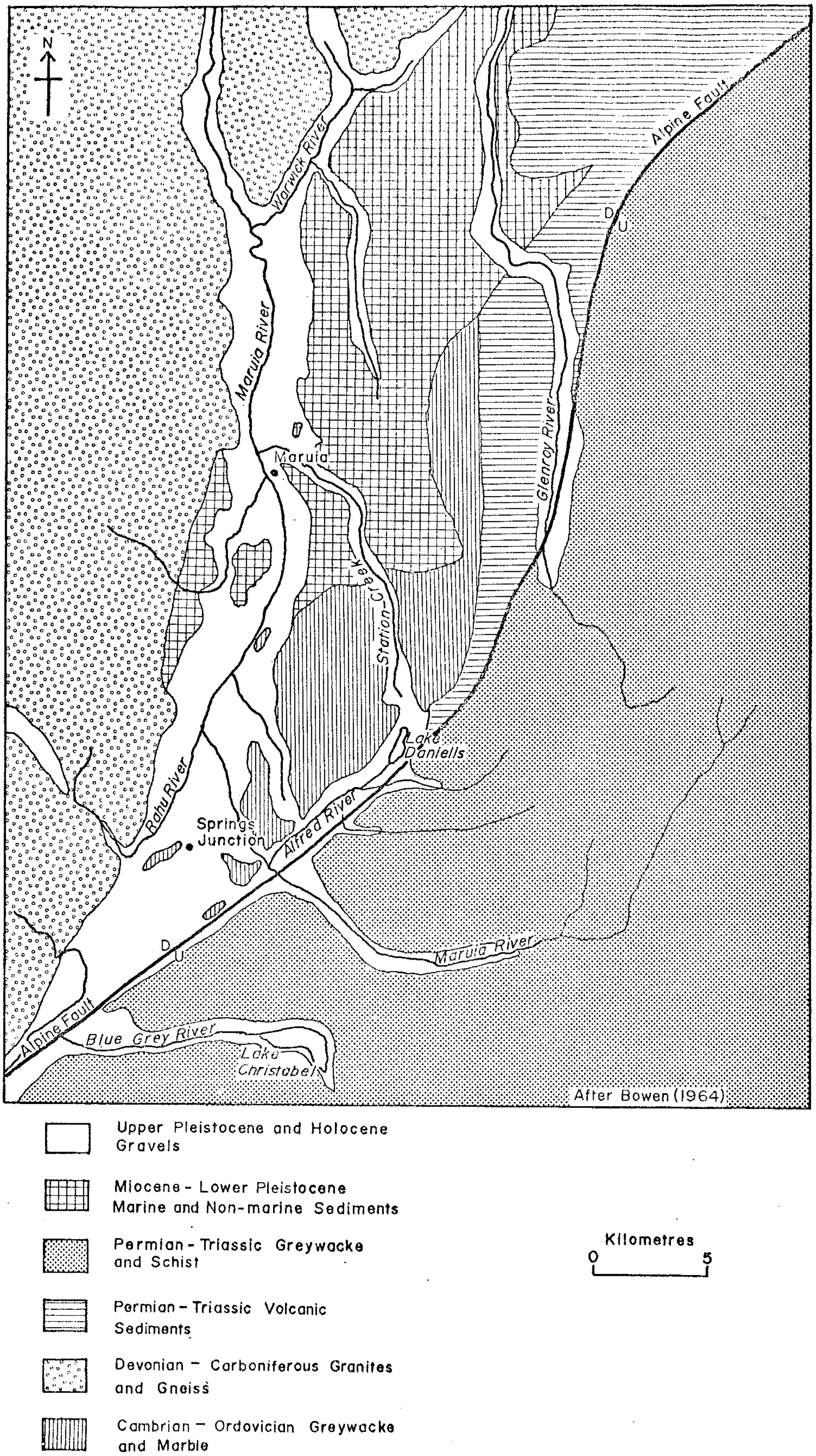

Fig. 3 Generalized Geology map of the Maruia-Springs Junction area.

shallow northward closing, north-south trending syncline.

The dominant structural feature of the area is the important transcurrent Alpine Fault. Distinctive rocks and structural features on the western side of the fault can be observed in the Nelson Lakes Region. These features are continued on the eastern side of the fault 400 km south in Central Otago. Initially it was believed that this displacement occurred during the Rangitata Orogeny 140 million years ago (Suggate 1963). The more widely accepted view at present is that the displacement occurred over the last 11 million years during the Kaikoura Orogeny, which began in the Late Miocene and culminated during the Lower Pleistocene (Sheppard et.al. 1975). This orogenic phase resulted in the uplift of the Southern Alps.

The varied geologic makeup of the study area is reflected in the relief of the study area. In the Upper Maruia Valley the river is confined in a narrow steep sided valley. This is the area of schist and greywacke. Rapid regional uplift has meant that the Maruia River and the glacier, had to be continually adjusting to changing base-levels. Thus the river has been actively downcutting, creating a deep narrow valley. The Middle Maruia lies west of the Alpine Fault. Uplift has not been vigorous here. Therefore the river has been able to widen its valley. North of Maruia where the river flows through the soft easily eroded Rappahannock Group conglomerates, the valley attains its greatest width. (Fig. 5).

Fig. 5. Middle Maruia Valley looking up valley from above the Creighton I moraine loop. Prominent terrace level in middle distance is part of the Creighton II outwash surface. Victoria Range on skyline at right. Spenser Mountains on skyline at centre and left.

The diverse lithologies in the region proved useful in determining the provenance of some of the gravel deposits in the Middle Maruia Valley.

III. LATE CAINOZOIC GEOLOGIC HISTORY OF STUDY AREA.

The late Cainozoic geologic history of the study area is dominated by the Kaikoura Orogeny. These earth movements began in the Late Miocene, and reached a peak in the

Lower Quaternary. (Sheppard et al. 1975). The orogeny is probably continuing at present. From the Late Miocene to the Early Quaternary the 400 km displacement along the Alpine Fault occurred, and 5 km of uplift occurred in the Haast Schist and Torlesse Group terrains east of the Alpine Fault. (Sheppard et al 1975). The Rappahannock Group conglomerates were laid down in a shallow non-marine intermontaine basin from the Late Miocene to Lower Quaternary (Cutten 1976). They are typical molasse deposits derived from the rapidly rising Spenser Mountains. They may in part be glacial in origin like their correlatives the Old Man Gravels (Bowen 1967). Unconformably overlying the Rappahannock Group are the gravel deposits relating to the Late Quaternary Glaciations. The intervening period which is not represented by any deposits in the Maruia Valley is probably greater than 1 million years. The rapid uplift of the Spenser Mountains has not continued in the Upper Quaternary. The glacial and fluvio-glacial gravels are too young to have been much deformed by the Kaikoura orogenic movements (Fleming 1975).

The record of the last of the Quaternary glaciations, the Otiran, is extensive in the Middle Maruia Valley. Evidence for earlier glacial episodes is not so widespread. In the Lower Maruia Valley Fyfe (1935) mapped a discontinuous dissected terrace level 100 m above the river. Two lower terrace levels can in places be seen. These three terrace levels may very tentatively be correlated from highest to lowest, as remnants of outwash aggradational surfaces relating to the Waimungan, Waimean, and Otiran Glaciations. Both higher terraces can be seen near the downstream mouth of the Gorge. Thus during the Waimungan and Waimean Glaciations ice probably did not extend far into the Lower Maruia Valley. The record of the Otira Glaciation in the Middle Maruia Valley is the subject of this study.

IV. THE MARUIA GLACIER.

The Spenser Mountains form the northern extension of the Southern Alps. They were one of the northernmost mountain ranges to be extensively and repeatedly glaciated during the Late Pleistocene (Suggate 1965). Major valley glaciers extended down the Maruia, Glenroy, Matakitaki, Travers, Wairau, and Waiau valleys. Of these the Maruia was the southernmost, and in its lower reaches occupied the broadest valley.

The glacial deposits preserved in the Middle Maruia Valley are believed to have been deposited during the most recent Otiran * Glacial Stage, and a minor fluctuation since that time. A wide range of morphological and depositional glacial and fluvio-glacial features have been preserved in this part of the valley. End and lateral moraines, outwash, degradational and kame terraces can all be seen. Tills, deltaic deposits, and lake beds are also preserved. Numerous small cirques can be seen on the flanks of the Victoria Range. Other classic glacial features such as "U" shaped valley cross-profiles and truncated spurs are also present in abundance.

Five main advances in two groups can be recognised

* The Otiran Glacial Stage as defined by Suggate (1965 p.83) for the Grey River-Taramakau River area.

in the Middle Maruia Valley; the Creighton I, II, III, and Reid Stream I, II advances. A minor re-advance, the Springs Advance, occurred after the Reid Stream II advance. However ice did not reach the Middle Maruia Valley. The limits of the five main advances in the Middle Maruia Valley are shown on Fig. 6. The major cirques are also marked. The Victoria Range contains over thirty cirque-like features. Only the major ones have been shown on Fig. 6.

The Maruia glacier flowed from two cirques at the southern end of the central massif of the Spenser Mountains. The ice streams from these two cirques coalesced about 1 km west of the Ada Pass (grid ref. S46/871053). The valley forms here suggest that some ice from the Maruia Glacier must have flowed over this low pass and down the Ada Valley to join the Waiau glacier. Such an ice tongue was mapped by Suggate (1965) and Clayton (1968). As the Ada valley is more or less continuous with the Maruia Valley this ice tongue was probably fed by ice from the Maruia glacier.

The Maruia glacier flowed south-west for 15 km to the Lewis Pass. (2 km upvalley of this it was joined by the small Kiwi glacier.) The Lewis Pass is 865 m a.s.l. and only 150 m above the present Maruia riverbed. The Lewis River rises near the Pass and flows due south down a straight glaciated valley for 15 km where it joins the Boyle River. At the level of the Lewis Pass the Lewis Valley is continuous with the Right Hand Branch of the Upper Maruia Valley. Thus for most of the ice in the Maruia glacier higher than about 130 m above the valley floor, the Lewis valley would have provided the easiest flow path. A large tongue of Maruia ice is shown extending down the Lewis valley during

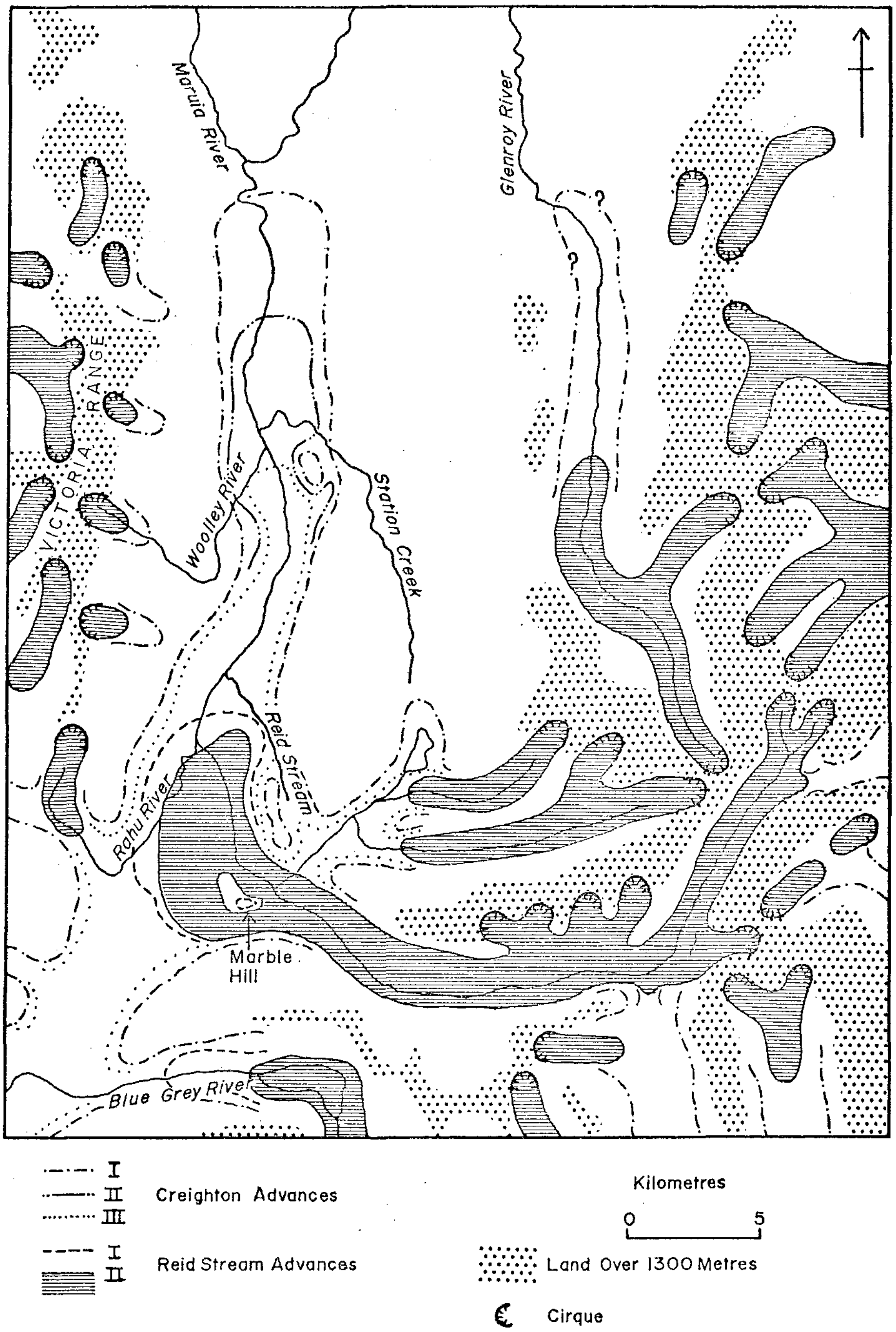

Fig. 6 Limits of Otiran ice advances in the Middle Maruia Valley. Complete ice cover is shown only for the youngest (Reid Stream II) ice advance. During the earlier advances it will have been greater, in keeping with the greater length of the Maruia glaciers.

the earlier Otiran advances by Suggate (1965) and Clayton (1968). That much of the ice in the Maruia glacier flowed down the Lewis Valley is suggested by the varying valley widths of the Right Hand Branch of the Maruia Valley north and west of the Lewis Pass. Upvalley, north 2 km from the Pass, the valley is 950 m wide at the 900 m contour. Downvalley, west 1 km from the Pass the valley is only 650 m wide at the 900 m contour. This unusual variation in valley widths cannot be attributed to variations in the rock types in the area as they are uniform greywackes. Thus it is probable that variation is due to a large proportion of the ice in the Right Hand Branch of the Mariua River flowing south over the Lewis Pass, and not west down the Upper Maruia Valley. Indeed it is likely that earlier in the Pleistocene all ice in the Right Hand Branch of the Maruia Valley flowed down the Lewis Valley. The upper layers of ice in this north-south flowing glacier probably spilled over a col into the then much shorter Upper Maruia Valley. This tongue of ice must have gradually lowered the col until by the very latest Pleistocene, this became the major flow direction for ice in the Right Hand Branch of the Maruia Valley.*

Downvalley from the Lewis Pass ice in the Maruia Valley flowing due west was joined by several tributary glaciers from the southern slopes of the Freyberg Range. These glaciers flowed from the valleys of the two branches of the Left Hand Branch of the Maruia River, and from Jack

* Such a process of glacial diffluence was described in the Scottish Highlands by Linton (1949).

Creek. (Fig. 6).

In the Upper Maruia Valley the glacier flow regime was relatively simple. Confined to a narrow steeply inclined valley the glacier was able to flow rapidly with nothing to obstruct it. However in the broader less inclined Middle Maruia Valley the glacier could spread out and thin. As a result it would probably have flowed more slowly. Its flow would have been obstructed in several places by various rock outcrops.

Lower Paleozoic rocks outcrop across the lower end of the Upper Maruia Valley (Fig. 3). These rocks formed the first major obstruction to the flow of the glacier. While much of the ice flowed straight across this body of rock, some was forced to flow in other directions. During the earlier Creighton Advances some Maruia ice was forced to flow north-east up the Alfred Valley. Some flowed down the valley of Reid Stream to rejoin the main glacier. The rest joined ice from the Alfred, and Pell Stream valleys to flow into the depression, now occupied by Lake Daniells, into the upper reaches of Station Creek. (Fig. 6). Another tongue of Maruia ice exploited the Alpine Fault crush zone immediately south-east of Marble Hill. State Highway 7 now passes through this passage. During the Creighton advances ice probably completely covered Marble Hill, and extended 25 km down the Middle Maruia Valley. The later Reid Stream advances, which only extended 8 km down this part of the valley were split into two streams by Marble Hill. (Fig. 7).

Fig. 7. Upper Maruia Valley. Springs Junction in the foreground. Marble Hill to the right in the middle distance. Mt. Meuller on the skyline to the left. Low ridges to the left of Marble Hill are ground moraine deposited during Reid Stream I and II Advances.

While the bulk of Maruia ice flowed north, some ice probably flowed south towards the Upper Grey Valley. The Upper Grey Valley also contained ice, which was flowing south. In the depression between the Maruia and Upper Grey valleys ice from both streams probably coalesced. During the Creighton Advances this area probably contained a large body of more or less stagnant ice derived from both glaciers. During the Reid Stream Advances the depression appears to have been substantially ice free. The glacial history of this area between the Upper Grey and Maruia Valley is complex and will be discussed below.

In the Middle Maruia Valley 8 km north of Springs Junction is a small outcrop of cambrian marble. The 1 km by 0.5 km body of rock, while never forming a major obstruction to the glacier, has been smoothed and streamlined by ice action.

Near the township of Maruia a belt of Upper Tertiary strata outcrops across the valley. As a result of the congestion caused by the narrowed valley, some ice was forced to flow over a low saddle 1.5 km southeast of Trig 3981 (grid ref. S39/662185), into Station Creek.

In the remaining 8 km to the forward moraine loop near Creighton Road, the flow of the glacier was unobstructed.

To Summarise, ice in the Maruia glacier was derived from five major cirques. During the Creighton Advances these cirques supported over 85 km of glacier. Rising at 1700 m a.s.l., the glacier flowed rapidly down its steep Upper Valley losing 1250 m elevation in this 30 km stretch. Flowing a further 30 km down the Middle Maruia Valley the glacier lost a mere 80 m elevation. In this part of the valley the glacier spread out, thinned, and flowed more slowly.

CHAPTER III.

THE GLACIAL ADVANCES OF THE MIDDLE MARUIA VALLEY

I. INTRODUCTION

The glacial and fluvio-glacial deposits preserved in the Middle Maruia Valley record the advances and retreats of the Maruia glacier during and since the Otiran Glacial Stage. An Otiran age is suggested by the lack of weathering of the deposits, and the continued existence of many of the finer details of the original surface form. No extensively preserved glacial, or fluvio-glacial deposits occur in the Upper Maruia Valley, therefore it is probable that those deposits in the Middle Maruia Valley were laid down during the last (Otiran) Glaciation. An Otiran age, at least for the Reid Stream Advances, can be assumed from the date of 14,800 years obtained from a moss peat just below some Reid Stream I Advance outwash gravels. (Suggate 1965). As the gap between the Reid Stream and Creighton Advances is not believed to be of interglacial proportions, the Creighton Advances may also be assumed to be of Otiran age.

Two major groups of advances can be recognised in the Middle Maruia Valley, the Creighton and Reid Stream advances. A minor re-advance, the Springs Advance, which occurred during the final retreat of the Maruia glacier is also recognised. During the Springs Advance ice did not reach as far

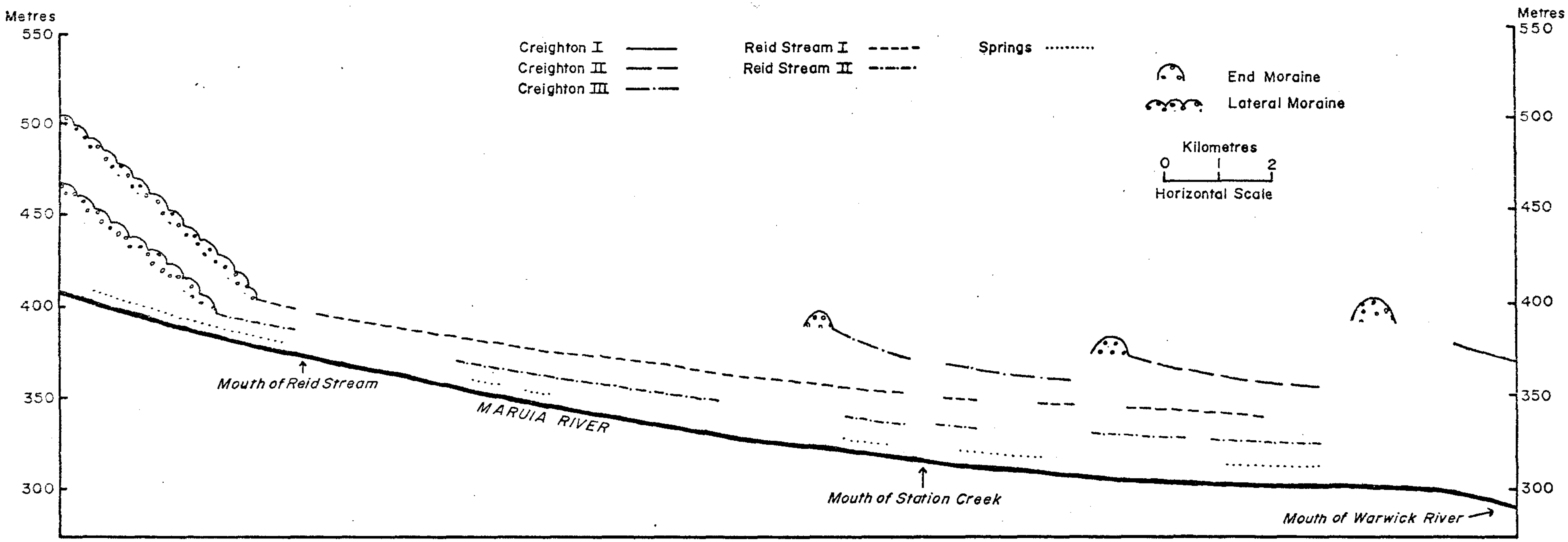

Fig. 8. Profiles of moraines and outwash surfaces in the Middle Maruia Valley.

as the Middle Maruia Valley. The vertical relationships between the moraines and outwash surfaces of the various advances are shown in Fig. 8. The diagram exemplifies the distinction between the two main groups of advances. The Creighton deposits which outcrop in the downstream part of the Middle Maruia Valley are higher above the present river-bed than Reid Stream deposits. The Reid Stream advances only reached to the upstream end of the Middle Maruia Valley. Their outwash surfaces are much lower than the Creighton outwash surfaces.

II. THE CREIGHTON ADVANCES.

This group of advances is named from Creighton Road which crosses the Creighton I outwash surface just downvalley of the Creighton I moraine loop.

Deposits relating to the Creighton Advances are widespread in the Middle Maruia Valley north of Maruia settlement (Fig. 4.). South of this point there are several isolated groups of deposits and topographic features which are believed to relate to these advances.

(1) Creighton I Advance

The forward moraine loop in the Middle Maruia Valley was deposited during this advance. The moraine loop, which is up to 100 m above the river, and 45 m above its outwash surface, lies 2 km up valley from the Warwick-Maruia River junction. (Figs. 9 and 10.) On the eastern valley side the topography is fresh. A well developed lateral moraine can be traced nearly 5 km up valley from the terminal loop (Fig. 4.) On the western valley side no lateral moraine has

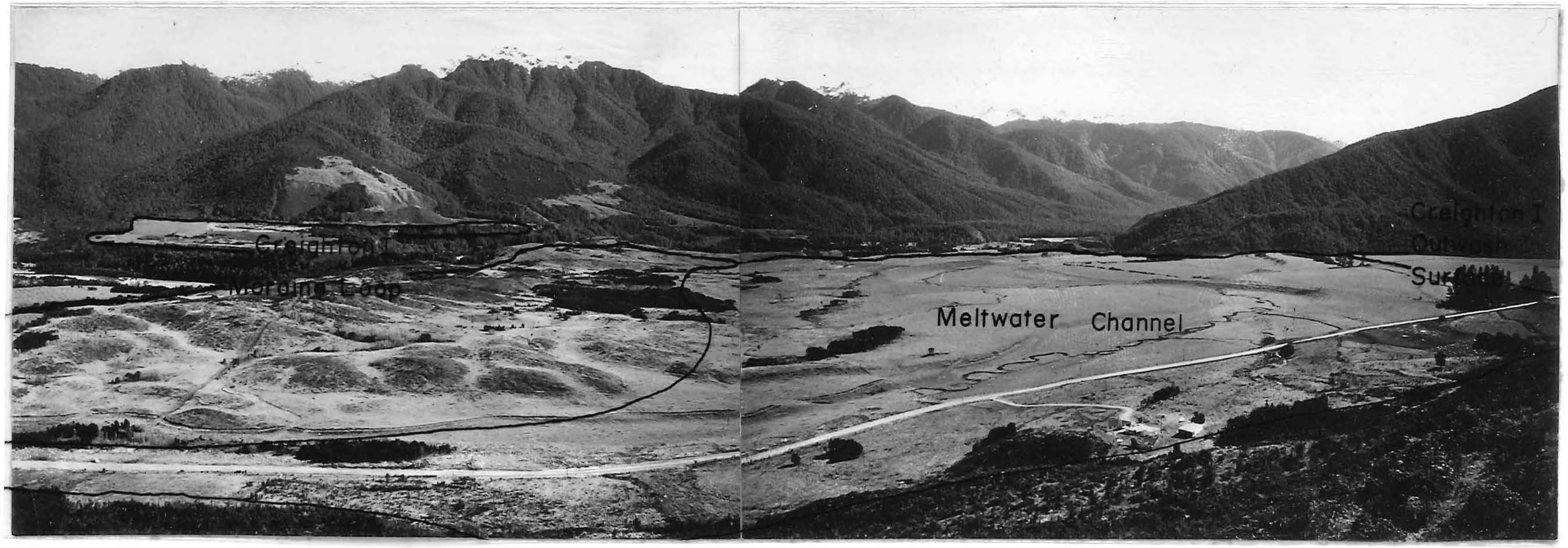

Fig. 9. Creighton I moraine loop (left) and outwash surface (extreme right) separated by a meltwater channel and associated terrace system. Victoria Range in background.

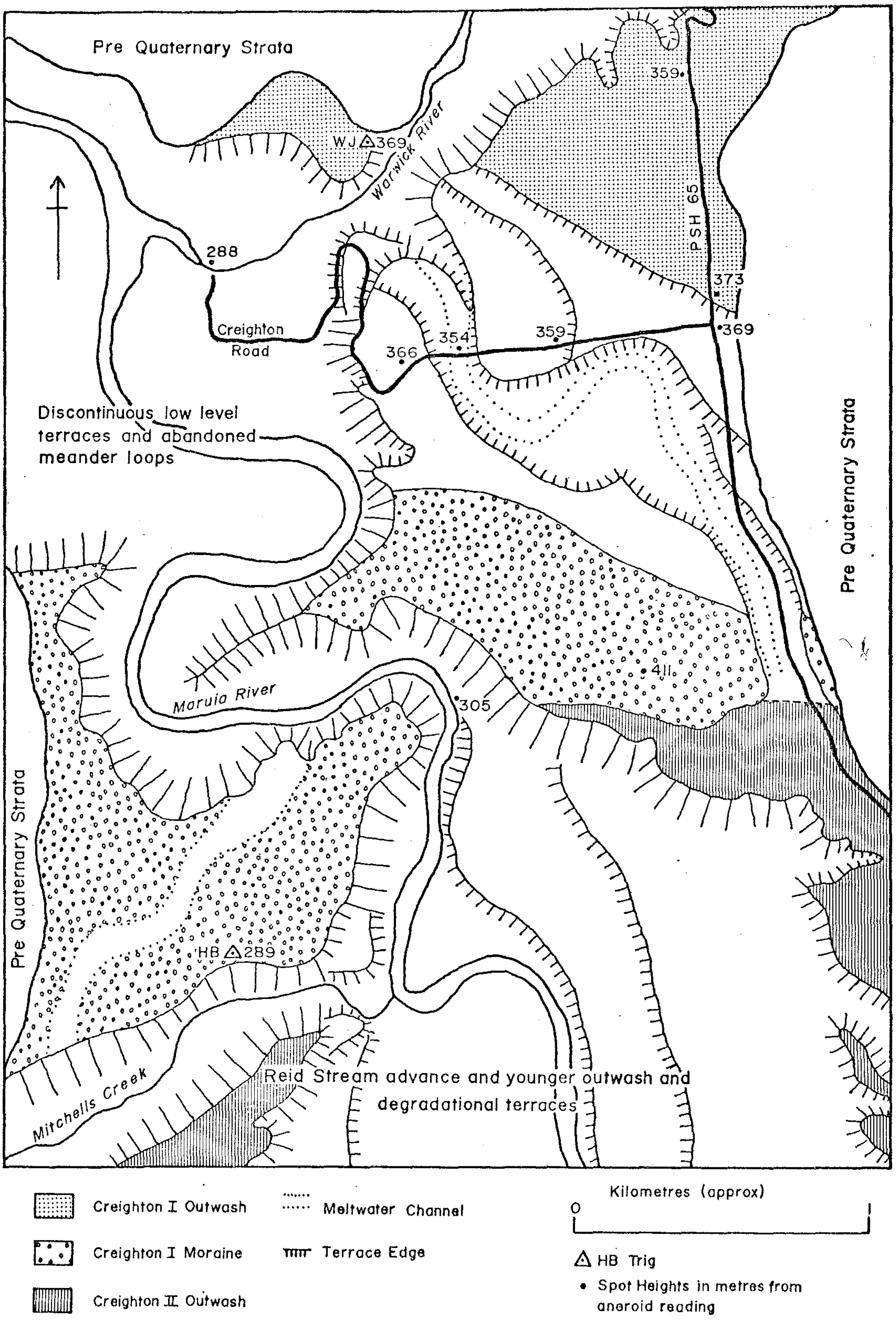

Fig. 10. Map of meltwater channels in Creighton I moraine and outwash surface.

been preserved. The terminal loop, which lies between the two limbs of a large meander of the Maruia River, has been reduced to a remnant which rises about 65m above the river. This part of the moraine loop was probably eroded by Mitchell Creek which flows from the Victoria Range. From the aerial photographs a dry stream channel can clearly be seen traversing the remnant. This channel was probably occupied by Mitchell Creek whose valley floor is at present incised over 30 m below the level of the moraine loop remnant. (Fig. 10).

The outwash surface of the Creighton I advance lies over 60 m above the river. It cannot be traced downstream into the gorge, although a narrow remnant can be traced up the eastern side of the Warwick River Valley to just beyond the Warwick-Rappahannock River junction. (Fig. 4).

In front of the moraine loop on the eastern valley side a large meltwater channel meanders across the outwash surface. (Figs. 9 and 10). Several degradational terraces flank the floor of this channel which is just under 20 m below the level of the outwash surface. The channel can be traced to an area between the end of the moraine loop and the eastern valley flank. A glacier margin stream probably flowed across the outwash surface. The cutting of this channel must have occurred after the formation of the outwash surface but before the glacier had retreated from its terminal loop.

Although the topography of the Creighton I moraine loop is well preserved, no exposures of associated till were found. However good exposures of Creighton I outwash were found.

At grid ref. S39/647295 the following sequence appears beneath the outwash surface: (Fig. 11).

5 m Poorly sorted, nonbedded, subrounded grey gravels up to 50 cm across. Interpreted as proximal outwash gravels.

10 m Bedded, rounded grey gravels up to 50 cm across. Interpreted as outwash gravels.

Fig.11. Creighton I proximal outwash, and outwash gravels. Height of section 15 m.

The gravels are all unweathered and there is only slight weathering of the coarse-sand matrix. The sequence is only 250 m in front of the Creighton I moraine loop. The lower 10 m of outwash gravels were probably deposited while the glacier was advancing. The upper 5 m of gravels are typical of proximal outwash, deposited while the glacier was at or near to maximum extent.

In the roadside at grid ref. S39/662308 a 200 m long, 15 m high sequence of gravels is exposed beneath the Creighton I outwash surface thus: (Fig. 12).

10 m	bedded, rounded grey gravels up to 20 cm across.
5 m	interbedded rounded grey gravels up to 10 cm across, with fine sand and silt layers.

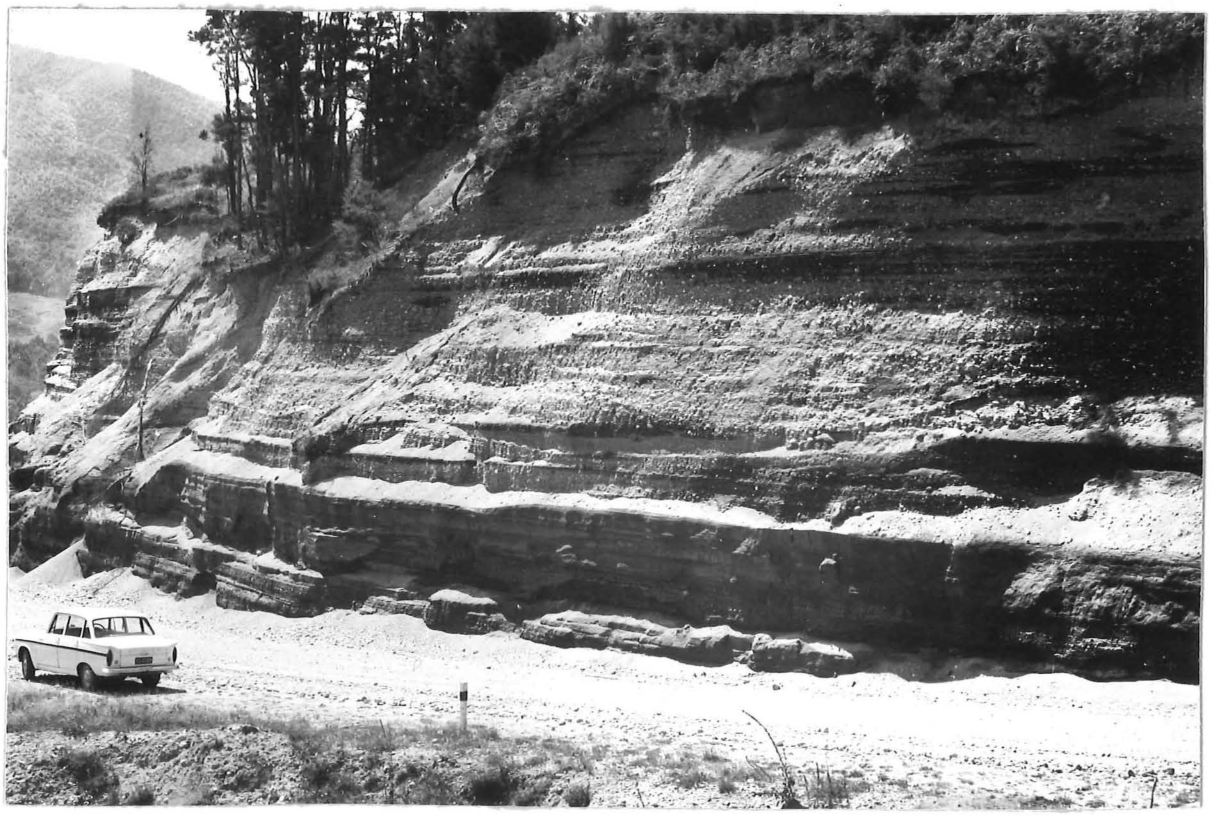

Fig. 12. Creighton I Outwash gravels with interbedded fine sand-silt layers. Vehicle and hammer for scale.

The silts are laminated, and the fine sands are cross-bedded and both occur together in bands up to 1 m thick. At the southern end of the section is a small exposure of till (Fig. 13):

4 m Non bedded isolated pebbles up to 15 cm across in a weathered coarse sand matrix.

Fig. 13. Terrace edge in pre-Creighton I till, buried by Creighton I outwash gravels.

The upper layers of the interbedded sands and gravels abutt against what appears to be a buried terrace face cut in the till. The till is significantly more weathered than the outwash gravel so is probably much older than the Creighton I

Advance deposits. The only possible source of this till was a tongue of ice from the Maruia Glacier extending up the Warwick Valley during an advance which significantly predates the Creighton I episode. After the ice melted away the till was terraced, presumably by the Warwick River. During the Creighton I advance outwash gravels extended up the Warwick Valley obstructing the flow of the Warwick River and causing extensive ponding. The ponds were successively infilled by outwash deposits as the Maruia glacier continued to advance. In this way the interbedded sand and gravel layers were built up. The absence of the sandy layers in the upper 10 m of the outwash gravels suggests that as the Creighton I advance neared its maximum extent the flow of the Warwick River was no longer obstructed. However, whether it continued to flow southwards, or flowed northwards through the Shenandoah Saddle is not known. The saddle is occupied by extensive alluvial fans, thus any evidence of a possible former channel through there has been obliterated.

<u>Summary of the Creighton I Advance</u>.

It is very likely that the Creighton I advance was the first Otiran advance in the Maruia Valley. This cannot be proved, although several factors would suggest that there was probably an interglacial, or at least a long time interval between the Creighton I advance and that which immediately preceded it. Creighton I outwash gravels can be seen at river level, which suggests that prior to this advance the Maruia River had cut itself down to, and probably beyond, its present level. Only one exposure of pre-Creighton I deposits was seen. This was the till underlying the Creighton I outwash gravels. The till is significantly weathered, in contrast to the almost unweathered outwash gravels. Therefore a considerable time must have elapsed between the deposition of the till and the outwash gravels. Thus, before the Creighton I advance the Maruia River was able to lower itself to or below its present level, and had removed almost all the evidence for a preceding advance of the Maruia glacier. The Creighton I advance is therefore believed to be the first Otiran advance of the Maruia glacier.

It is not known how far the Maruia glacier had receded before the Creighton I advance. It may well have disappeared entirely. The advance, which resulted in the most impressive moraine loop to be preserved in the Maruia Valley caused over 60 m of river aggradation.

(2) The Creighton II Advance

Only part of the Creighton II moraine loop has been preserved. It can be seen on the eastern valley side 4 km up valley from the Creighton I moraine loop. (Fig. 4). No continuation of the moraine loop can be seen on the western valley side. The morainic topography on the preserved remnant has been substantially reduced, probably by the two streams which traverse it. The moraine loop rises 75 m above the river and less than 30 m above its outwash surface (Fig. 8). The outwash surface, which is 50 m above the river can be traced downvalley to the Creighton I moraine loop.

Till is exposed in the banks of the two streams which have incised deep channels through the moraine loop. 5 km due north of Maruia, Provincial State Highway 65 crosses an unnamed stream. 750 m due west of this point at grid ref. S39/657236 the stream is incised 10 m below the level of the Creighton II moraine. The following sequence is exposed.

3 m non-bedded, subrounded gravel up to 10 cm across with fine-sand lenses. Interpreted as till.

6 m bedded, rounded gravels up to 10 cm across. Interpreted as outwash gravels.

The outwash gravels dip at a low angle west towards the Maruia River. They appear to be local stream gravels derived from the east deposited in a channel cut through the moraine loop. The channel was probably cut soon after the Creighton II advance, while the phase of aggradation was probably associated with the younger Reid Stream advances.

About 750 m due north of the above exposure, a small stream, not marked on sheet S39, is incised below the level of the Creighton II outwash surface. At grid ref. S39/656244 a 20 m exposure of gravels can be seen in the stream's right bank beneath the outwash surface:

5 m Poorly bedded, subrounded gravels up to 20 cm across. Interpreted as proximal outwash

10 m Alternating layers of rounded gravels up to 10 cm across and fine sands.

5 m Horizontally bedded fine sand, and silt layers.

The lower sand and silt layers were probably deposited in a small lake left as the glacier retreated from its Creighton I position. The alternating sand and gravel layers were probably deposited as the glacier readvanced. The upper, proximal outwash gravels were laid down while the glacier was at, or near its Creighton II maximum.

2 km downvalley from the Creighton II moraine, in a cutting in Boundary Road, the following sequence appears beneath the outwash surface (grid ref. S39/662265).

3 m	Rounded gravels up to 15 cm across.
7 m	Rounded gravels up to 5 cm across, with bands of fine sand and silt up to 0.5 m thick. Interpreted as outwash.
1 m	Laminated grey clays. Interpreted as Lake beds.
10 m	Non bedded poorly sorted iron stained gravels up to 20 cm across. Interpreted as subglacial till.

The subglacial till is unweathered and is thus not a correlative of that exposed beneath the Creighton I outwash gravels. (p. 31). The till does not appear to have been modified by meltwater. The contact between the till and the lake bottom clays is undulating and no erosion of the till appears to have occurred before the clays were deposited. It is believed that after the glacier retreated from its Creighton I position, a lake became impounded behind the moraine loop. The laminated clays accumulated in this lake. The underlying subglacial till became iron stained by percolating water from this lake. The gravels in the upper part of this section were deposited during the Creighton II advance. They are typical horizontally bedded fluviatile gravels and become coarser towards the top of the section. They do not show any structures associated with advancing deltas, as would be expected had they been deposited in a lake. Thus it is believed that the lake had been drained prior to the Creighton II advance.

Summary of the Creighton II Advance.

It is not known how far up valley the glacier receded from its Creighton I position. In this downvalley portion of the Middle Maruia Valley the glacier would have been wide and slow moving. A minor reduction in ice flow in the Upper Maruia Valley would have caused a significant retreat in the lower reaches of the glacier. This retreat would probably have occurred as downwasting of the glacier rather than as rapid terminal face recession.

As the glacier retreated a lake became impounded behind the Creighton I moraine loop. This lake was probably drained before the glacier began to readvance.

There does not appear to have been a long gap between the Creighton I and II advances. There is no evidence for extensive downcutting by the Maruia River during this time. During the advance at least 15 m of river aggradation occurred. However the Creighton II outwash surface cannot be traced downstream of the Creighton I moraine loop.

(3) The Creighton III Advance

Only a minor remnant of the moraine loop of this advance has been preserved. It lies 70 m above the river at grid ref. S39/657183. A lateral moraine relating to this advance can be traced nearly 4 km up valley from this point. This lateral moraine is below the level of the low saddle 1.5 km southeast of Trig 3981. Thus ice probably did not occupy this saddle during the Creighton III advance. The outwash surface which is 50 m above the river can be traced from the remnant of the moraine loop 5 km downvalley to the Creighton II moraine loop. A high terrace on the northern bank of Manuka Creek on the western valley side, was probably part of the Creighton III outwash aggradation surface.

No exposures of Creighton III till were found. However in Deep Gully Creek * at grid ref. S39/661221 the following section appeared beneath the outwash surface: (Fig. 14).

Fig. 14. A section through the Creighton III outwash surface. Height of section 30 m.

* This is a local, and AA Nelson name. Shown on NZMS 1 S39 as "Shingle Creek".

12 m	horizontally bedded, rounded gravels up to 5 cm across, in coarse sand matrix. Interpreted as outwash gravels.
1 m	horizontally bedded coarse sand. Interpreted as topset beds.
12 m	moderately dipping coarse sand beds, with some fine gravel layers. Interpreted as foreset beds.
3 m	sticky grey laminated clay. Interpreted as lake bottom beds.
2 m	non bedded subrounded gravels up to 10 cm across in coarse sand matrix. Interpreted as subglacial till.

This sequence spans the time interval from the retreat of the Maruia glacier from its Creighton II position, to the maximum of the Creighton III advance. The subglacial till was deposited during the Creighton II advance. As the glacier receded from its Creighton II position a lake became impounded behind the moraine loop. The laminated grey clays were deposited in this lake. Although the individual lamellae are still preserved, the whole band appears to have slumped. This may have been caused either by the weight of the overlying sediment, or the slumping of the underlying tills as dead ice melted may have caused the disruption of the lake beds. The foreset beds overlying the lake beds dip west towards the Maruia River. Thus they were not deposited by the Maruia River, but were probably derived from the nearby Station Creek. The coarse sand overlying these foreset beds is interpreted as a topset bed because there is no obvious erosional contact between these two units. Such a contact would be expected if the sand layer was to be interpreted as the lowest unit of the outwash gravels. If this latter was the case, the topset beds would be missing, implying a period of erosion which is not recorded in this sequence.

Summary of the Creighton III Advance.

This advance was the smallest of the Creighton Advances. As the Maruia glacier had retreated from the Creighton II position, a lake was impounded behind the moraine loop. The lake was substantially infilled by local stream deposition before these deposits were engulfed by outwash gravels as the Maruia glacier advanced to its Creighton III position. As with the Creighton I and II advances, there is no evidence for extensive downcutting between the Creighton II and III episodes. Thus the time interval between the two advances was probably not long. During the Creighton III advance at least 25 m of river aggradation occurred.

(4) Other Deposits and Landforms Relating to the Creighton Advances.

Most of the deposits and landforms described in this section were formed after the Creighton III advance. However they are described here as they are not believed to be significantly younger than the Creighton III deposits, and they are not features of the Creighton-Reid Stream Interstadial described below.

South of Maruia, the Reid Stream deposits are in several places underlain by what are interpreted as Creighton III deglacial gravels.

Fig. 15. Creighton III deglacial gravels underlying
Reid Stream II outwash.
Height of section 8 m.

A typical exposure of these gravels can be seen at grid ref. S39/660139 beneath the Reid Stream II outwash surface: (Fig. 15).

2 m Rounded grey gravels up to 15 cm across. In a coarse sand matrix. Interpreted as Reid Stream II outwash gravels.

3 m Rounded gravels up to 10 cm in a very slightly weathered coarse sand matrix, with lenses of coarse sand. Interpreted as Creighton III deglacial gravels.

The lower gravels show some undulatory bedding. They are probably reworked sub-glacial till.

8 km upvalley from the Creighton III end moraine remnant a series of deposits and landforms are preserved on the eastern valley side (Fig. 4). A small ridge of Cambrian marble 800 m long and 300 m wide outcrops in the valley floor. It is known locally as Ure's Hill and its highest point (Trig G A , grid ref. S39/648109) is 428 m a.s.l. This ridge has protected the deposits between it and the eastern valley flank from erosion by the Maruia River. At grid ref. S39/650107 a small ridge 200 m long, 30 m wide and 10 m high is cut by Provincial State Highway 65. Exposed in the road cutting is:

7 m Non-bedded subrounded gravels up to 20 cm across in coarse sand matrix, with lenses of coarse sand. Interpreted as till.

This feature is interpreted as a small terminal moraine deposited during the retreat of the Maruia glacier from its Creighton III position. Till deposits similar to these mantle the eastern flanks of Ure's Hill.

Opposite Ure's Hill on the eastern valley side is a high level irregularly sloping terrace. (Fig. 4). At its highest it is 75 m above the river. It is interpreted as a kame terrace deposited between the valley side and the shrinking Maruia glacier.

Further up valley a bench, 90 m above the Maruia river can be seen flanking Reid Stream where it emerges from the mountains (Fig. 4). This is also interpreted as a kame terrace deposited as the glacier retreated from its

Creighton III position.

(5) The Maruia-Upper Grey Valley Area.

The general geomorphology of this lowlying heavily forested area between the Middle Maruia and Upper Grey Valleys has been described above. The area was termed "the Alpine Fault Depression" by Suggate (1965 p.39). It is bounded on the east by the Alpine Fault and Haast Schists, and on the west by the Victoria Range Granites. (Fig. 3). To the north is the Middle Maruia Valley, and to the south is Palmers Flat (grid ref. S46/555933) where the Blue Grey, Brown Grey, and Upper Grey rivers meet. Running down the middle of the depression is a ridge of Cambrian greywacke and marble. (Farmer, 1967). The interpretation of the glacial history is based largely on supposition, as the area is heavily forested and exposures of gravel are rare.

Suggate (1965 p.39) states that in this area "two prominent moraine loops can be recognised." On this basis a large tongue of Maruia ice was considered to have extended almost to Palmers Flat during what are mapped herein as the Creighton advances. The present writer was unable to recognise any such moraine loops, either on the aerial photographs, or in the field. However several small ridges can be seen at the southern end of the Black Stream flats. They are roughly aligned north-east - south-west therefore cannot be terminal moraines. They have been mapped as ground moraine. (Fig. 4). Suggate also maps the extent of the earlier Otiran advances in the Upper Grey and its tributary valleys. (Suggate 1965 Figs. 17, 37). No ice is shown extending as far as Palmers Flat. Such a situation is quite anomalous considering that valleys adjacent to the Upper Grey Valley are shown with extensive glaciers. The Upper Grey Valley appears to be a typical alpine valley exhibiting the usual features of a comparatively recently glaciated valley. To postulate no ice in this valley during the Otira Glaciation is puzzling. Ice must have occupied the depression during this time as several exposures of unweathered till can be seen. These are in the southern part of the area, which at present drains into the Upper Grey Valley. The till is mostly only a few metres thick, and appears to be a veneer deposited over hard rock.

During the earlier part of the Otira Glaciation ice from the Brown Grey, Blue Grey, and May Creek valleys probably coalesced at Palmers Flat to flow south down the Upper Grey valley. This valley is 1.5 km wide at the 600 m level. However the combined widths of the Blue Grey, Brown Grey and May Creek valleys at this level is 2.25 km. Thus there was probably substantial congestion at Palmers Flat with more ice arriving than could be easily removed down the Upper Grey Valley. Some ice may have been forced to flow northwards towards the Maruia Valley. It is likely that this tongue of Upper Grey ice coalesced with a tongue of southward flowing Maruia ice thus to fill the depression. Subglacial till was probably deposited over the entire area during this time.

Due to its positioning between the Maruia and Upper Grey Valleys, the glacial history of this area has been complex. Ice from both glacial systems probably entered the area so that during the Early Otiran advances ice cover was continuous between the Maruia and Upper Grey Glaciers. When the ice had melted away after the Creighton advances a veneer of till remained.

III. THE CREIGHTON-REID STREAM INTERSTADIAL.

By the end of the Creighton Advances the Middle Maruia valley north of Maruia had been filled with morainic and outwash gravel to a height of 400 m a.s.l. As the glacier retreated the Maruia River began to incise itself below the level of these deposits. All but small remnants of the deposits of the Creighton II and III on the western valley side were eroded away. A large part of the Creighton II outwash surface was also removed from the eastern valley side. (Fig. 4). However the Creighton I moraine loop was not significantly affected during this period of downcutting. The Maruia River merely incised itself in a series of meander loops through the moraine.

It is not known how much downcutting occurred in this period. Deposits relating to the subsequent Reid Stream advances can be seen at river level. Thus downcutting must have reached a level below that of the present river bed. This gives a minimum figure for the amount of downcutting below the level of the Creighton III outwash surface of 50 m.

After this period of downcutting a large lake became impounded in the Middle Maruia Valley. Suggate (1965 p.37) in mentioning this lake stated that it had been dammed by the Creighton II moraine loop. However lacustrine deposits can be observed beneath the Reid Stream outwash surfaces downstream of this moraine loop. It seems more likely that as much of the Creighton II moraine loop had been eroded before the lake came into existence it was impounded behind the Creighton I moraine loop. It appears that after the Creighton III advance the Maruia River incised itself in a deep narrow gorge through unconsolidated gravels of the Creighton I moraine loop. The sides of this gorge probably slumped thus damming the Maruia River. For convenience this lake will be referred to as Lake Maruia.

The impounding of Lake Maruia is believed to have occurred after the period of downcutting because lacustrine beds can be seen at river level. This implies that the lake bottom was at or below the present river level. Lake Maruia probably extended 15 km up valley from the Creighton I moraine loop to Ure's Hill. No lake deposits can be seen up valley from this point.

The most common lacustrine deposits are foreset beds. However south of Maruia a few exposures of laminated lake bottom clays overlain by foreset beds can be seen. The lake deposits are commonly found underlying the Reid Stream II outwash gravels. The Reid Stream I outwash gravels are poorly exposed in the Middle Maruia Valley downvalley of Ure's Hill. Nowhere can Reid Stream I gravels be clearly seen overlying lake deposits. However there are several reasons why the lake deposits are believed to be related to the Creighton III - Reid Stream I interstadial, and not the Reid Stream I - II interval. The lake deposits are commonly ironstained indicating that they were water saturated for some time after deposition. The contact between the foreset beds and the Reid Stream II gravels is everywhere unconformable. (Figs. 15, 17, 18, 19). The Reid Stream II gravels cannot therefore be interpreted as topset beds, as a period of erosion occurred sometime after the foreset beds were laid down and before the deposition of the outwash gravels. Thus for Lake Maruia to have existed between the closely spaced Reid Stream I and II advances would require that the following geomorphic events occurred during that interval: a period of extensive downcutting, followed by the damming of Lake Maruia, and the deposition of the lacustrine deposits, followed by a further period of downcutting before the Reid Stream II gravels were laid down. Given the close relationship of the two moraines and outwash surfaces such a series of geomorphic events between the Reid Stream I and II advances appears most unlikely. Therefore the lacustrine deposits are believed to have been laid down between the Creighton III and Reid Stream I advances.

The infilling of Lake Maruia resulted from aggradation associated with the readvance of the Maruia glacier.

This was the Reid Stream I advance. While the foreset beds are evidence of the existence of a lake, they were deposited as a result of the Reid Stream I advance and will therefore be described in more detail later. The laminated lake bottom clays are exposed in two sections below the foreset beds. For convenience, they too will be described below along with the foreset beds.

The period between the Creighton and Reid Stream Advances has been called an interstadial because of the number and magnitude of geomorphic events that occurred during that time. The Creighton deposits were extensively eroded and more than 50 m of downcutting occurred. A large lake became impounded behind the Creighton I moraine loop and extended upvalley at least 15 km from this point. The infilling of this lake occurred as a result of renewed river aggradation associated with the Reid Stream I advance.

IV. THE REID STREAM ADVANCES.

This group of advances is named after Reid Stream which cuts through the outwash surfaces near their origin.

Deposits relating to these two advances are widespread in the Middle Maruia Valley. While the glacier did not extend into the Middle Maruia Valley as far as Reid Stream, the outwash surfaces (Fig. 16) can be traced nearly 20 km downvalley as far as the Creighton I moraine loop. (Fig. 8). Lateral, and ground moraines have also been preserved up valley from the assumed terminal positions.

(1) Reid Stream I Advance

The terminal moraine loop for this advance has not been preserved. However extensive areas of lateral and ground moraine have been identified.

At grid ref. S46/635049 Provincial State Highway 65 crosses the Maruia River. The bridge is known locally as Williscroft's Bridge. On the hillside above, downvalley for 2 km a sequence of ridges, interpreted as lateral moraines are preserved. A high ridge is interpreted as a Reid Stream I lateral moraine. (Fig. 20). It is 90 m

Fig. 16. Reid Stream I and II outwash surfaces south of Maruia. Peak on skyline at left is Mt. Cann.

above the river and slopes downvalley until it merges with the Reid Stream I outwash surface which is 25 m above the river.

From opposite Reid Stream up valley to opposite Trig 4621 (grid ref. S46/609035) the lower slopes of the Victoria Range show a series of north-south trending ridges. These ridges, which are aligned roughly parallel to the valley, rise nearly 100 m above the river. Their height and shape suggest that they are lateral moraines deposited during the Reid Stream I advance. (Fig. 4), although the forest cover prevented detailed examination.

An area of ground moraine has been mapped northwest of Marble Hill. (Fig. 4 and 7). This is a hummocky area which rises 120 m above the river.

All these moraines are covered by beech forest. No exposures of the associated deposits could be found. Their interpretation as moraines is based upon their surface morphology.

The Reid Stream I outwash surface can be traced continuously from Reid Stream 8 km down the eastern valley side to above the West Bank Bridge over the Maruia River (grid ref. S39/656176). In this stretch no corresponding remnant can be seen on the western valley side. However north of Maruia remnants of the outwash surface are preserved on both sides of the valley. As the outwash surface is traced down valley it increases in height above the river. At Reid Stream it is 23 m above the river, at Station Creek 37 m, and on the western valley side opposite Warwick Junction (grid ref. S39/667264) it rises 43 m above the river (Fig. 8).

Reid Stream I Advance aggradation gravels are exposed in several placed. They include foreset beds, and normal fluviatile gravels.

At grid ref. S39/656180 the following sequence appears beneath the Reid Stream II aggradation surface: (Fig. 17).

3 m Horizontally bedded, rounded grey gravels up to 20 cm across. Interpreted as Reid Stream II outwash.

3 m Moderately dipping, rounded iron stained gravels up to 10 cm with coarse sand layers. Interpreted as foreset beds of Reid Stream I age.

1 m Laminated grey clays. Interpreted as Lake Maruia bottom beds.

1 m Poorly bedded rounded gravels up to 20 cm. Interpreted as deglacial gravels.

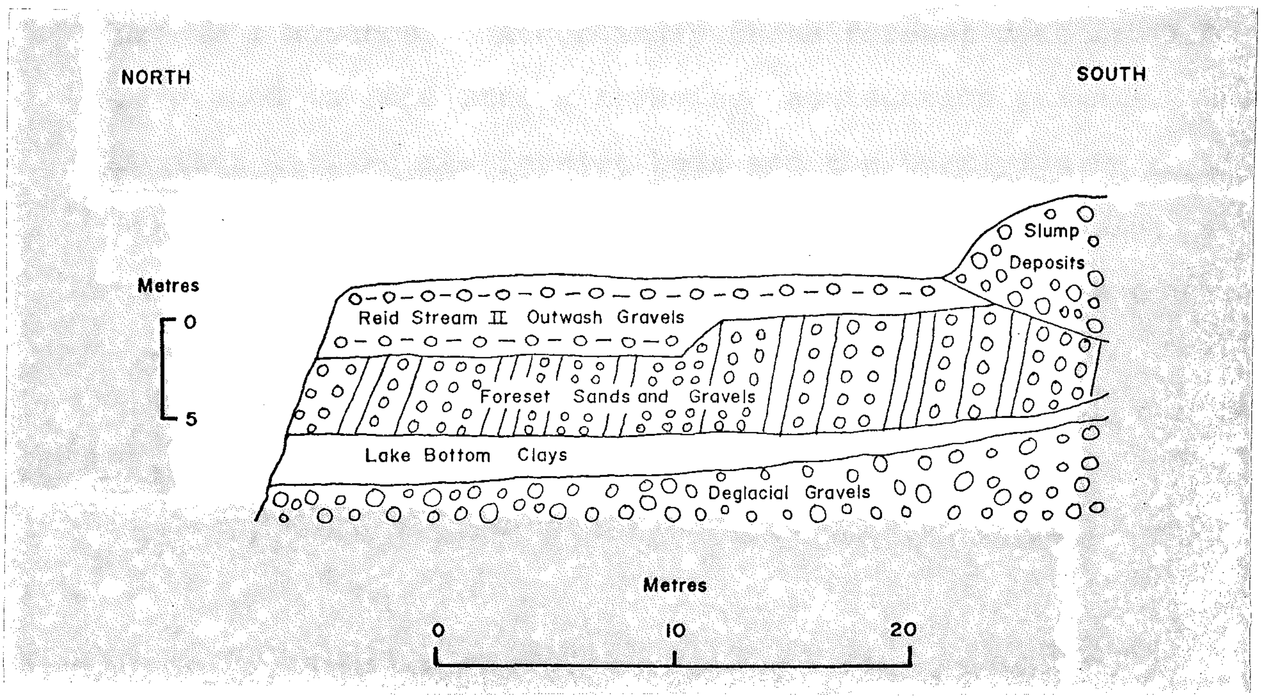

Fig. 17. Diagrammatic representation of deposits beneath the Reid Stream II outwash surface at grid ref. S39/656180.

The lowermost gravels in this section are of uncertain origin. This part of the section is partly overgrown and covered with slope wash. Large scale structures in these gravels cannot be seen, however there does appear to be some horizontal bedding. As they underlie the lake bottom beds they must have been laid down before Lake Maruia came into existence. They are tentatively interpreted as deglacial gravels laid down during the retreat of the glacier from the Creighton III maximum. The laminated grey clays are among the few exposures of Lake Maruia beds. They are overlain by foreset beds deposited during the Reid Stream I advance. The marked iron staining of these beds was probably due to their being water saturated for some time after deposition. The foreset beds are predominantly gravel. Thus the infilling of Lake Maruia at this point was the result of a phase of active aggradation by the Maruia River. This phase of aggradation was probably a result of the Reid Stream I advance. Accordingly these foreset beds are interpreted as Reid Stream I advance aggradation gravels. The contact between the foreset beds and the overlying Reid Stream II outwash gravels is unconformable. The relationships between these two sets of beds has been discussed above.

3 km up valley at grid ref. S39/661151 the following sequence appears beneath the Reid Stream II outwash surface: (Fig. 19).

Fig. 18. Reid Stream II outwash gravels underlain by Reid Stream I crossbedded foreset sands Approximate height of section 12 m.

2 m Rounded grey gravels up to 15 cm across. Interpreted as Reid Stream II outwash gravels.

Up to 8m Cross bedded coarse sand. Interpreted as Reid Stream I foreset sands.

1 m Moderately dipping laminated grey clay. Interpreted as Lake bottom beds.

Up to 8m Poorly bedded, rounded, slightly iron-stained gravels up to 10 cm across. Interpreted as Creighton III deglacial gravels.

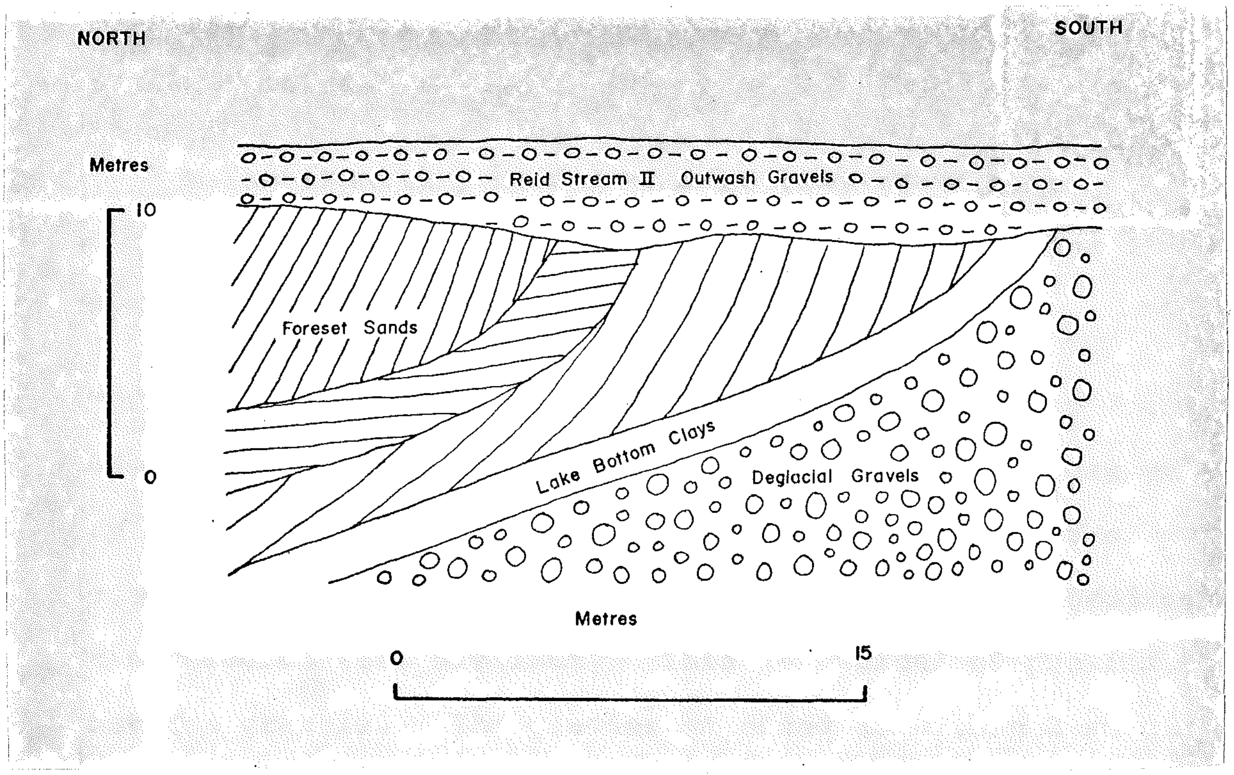

Fig. 19. Diagrammatic representation of deposits beneath Reid Stream II outwash surface at grid ref. S39/651151.

The lower gravels are very similar to the deglacial gravels described above (p.40).

The laminated grey clays are believed to be lake bottom beds deposited in Lake Maruia. The overlying foreset sands (Fig. 18) are cross bedded, and more than 10 m thick. The upper layers of these sands are not exposed. This sequence of crossbedded foreset sands was probably deposited on the front of a delta that was rapidly advancing into Lake Maruia. Thus these beds are believed to represent the initial phases of infilling of Lake Maruia associated with the Reid Stream I advance. The absence of gravels in these foreset beds would suggest that the advancing Maruia glacier was a long way from its maximum extent.

1 km down valley from Reid Stream at grid ref. S46/645193, the following section appears beneath the Reid Stream I outwash surface:

7 m horizontally bedded rounded grey gravels up to 15 cm across. Interpreted as Reid Stream I outwash gravels.

This was the only clear exposure seen of Reid Stream I outwash gravels. The lower 10 m of the section were masked by slope deposits. In the exposed gravels there is a coarsening towards the top of the section, and the bedding also becomes less distinct. This is typical of proximal outwash gravels. The glacier extended to within 2 km of this section at the climax of the Reid Stream I advance.

At grid ref. S39/657127 the following section shows beneath the Reid Stream I outwash surface:

3 m	Rounded grey gravel up to 15 cm across. Interpreted as Reid Stream I outwash gravel.
1.5 m	Sand, silt with thin peat band.
0.5 m	Sticky grey laminated clay. Interpreted as lake bottom beds.
1 m	Rounded gravel up to 15 cm across.

The section is mostly overgrown, but sufficient vegetation was removed to expose the above sequence. It is at the same location, and is essentially the same as that described by Suggate (1965 p.37). From the moss peat band in the sand and silt layer a radiocarbon age of 14,800 $\pm$ 230 was obtained (Grant-Taylor and Rafter 1971). Suggate (1965 p.37-39) interpreted the sands as representing "a pause in river aggradation, presumably the result of the temporary retreat after the formation of the high lateral moraines, (Reid Stream I) and before the formation of the low lateral moraine" (Reid Stream II). From both of these lateral moraines outwash surfaces can be traced downvalley. From the high lateral moraine the Reid Stream I outwash surface can be traced continuously downvalley well beyond the section described by Suggate (p. 45). The outwash surface under which the dated peat horizon lies must have been formed at the same time as the high lateral moraine. Thus, as the peat pre-dates the outwash gravels, the climax of the Reid Stream I advance must have occurred after 14,800 yrs B.P. The interpretation by Suggate of the date is clearly at fault. The peat cannot have been deposited during the interval between the Reid Stream I and II advances, as it was found below the Reid Stream I outwash surface, and more than 10 m above the Reid Stream II outwash surface.

The laminated grey clay layer is believed to have been deposited at the bottom of Lake Maruia. The overlying sands are analogous to those described in the section at grid ref. S39/661151 (p.52). Suggate (1965) reports Harris as saying that although no firm climatic interpretation could be drawn from the palynology of the peat band in the sands and silts, "neither fully cold nor fully warm conditions seem likely". This supports the correlation of these two sand layers as those at grid ref. S39/661151 were interpreted as having been deposited in the very early stages of the Reid Stream I advance when conditions would not have been fully glacial. Thus, if the sands and silts in this section represent aggradation in the early part of the Reid Stream I advance, this advance probably did not reach its maximum until about 14,500 yrs B.P.

(a) Summary of the Reid Stream I Advance

Prior to this advance the Maruia glacier had probably receded far into the Upper Maruia Valley. At least 50 m of downcutting occurred before the advance. As the glacier readvanced aggradation gravels filled Lake Maruia. At least 30 m of river aggradation occurred during this advance. A radiocarbon date on a peat layer in sands and silts laid down during the earlier part of this advance would suggest that it probably began about 15,000 yrs B.P. and reached a climax at about 14,500 yrs B.P.

(2) Reid Stream II Advance

As with the Reid Stream I advance, no terminal moraine loop has been preserved. However lateral moraines are preserved on both sides of the valley, and large areas of ground moraine have also been identified.

On the eastern valley side above Williscroft's Bridge a lateral moraine, 30 m below the Reid Stream I lateral moraine, slopes down valley to merge with the Reid Stream II outwash surface at grid ref. S46/644066. (Fig. 20).

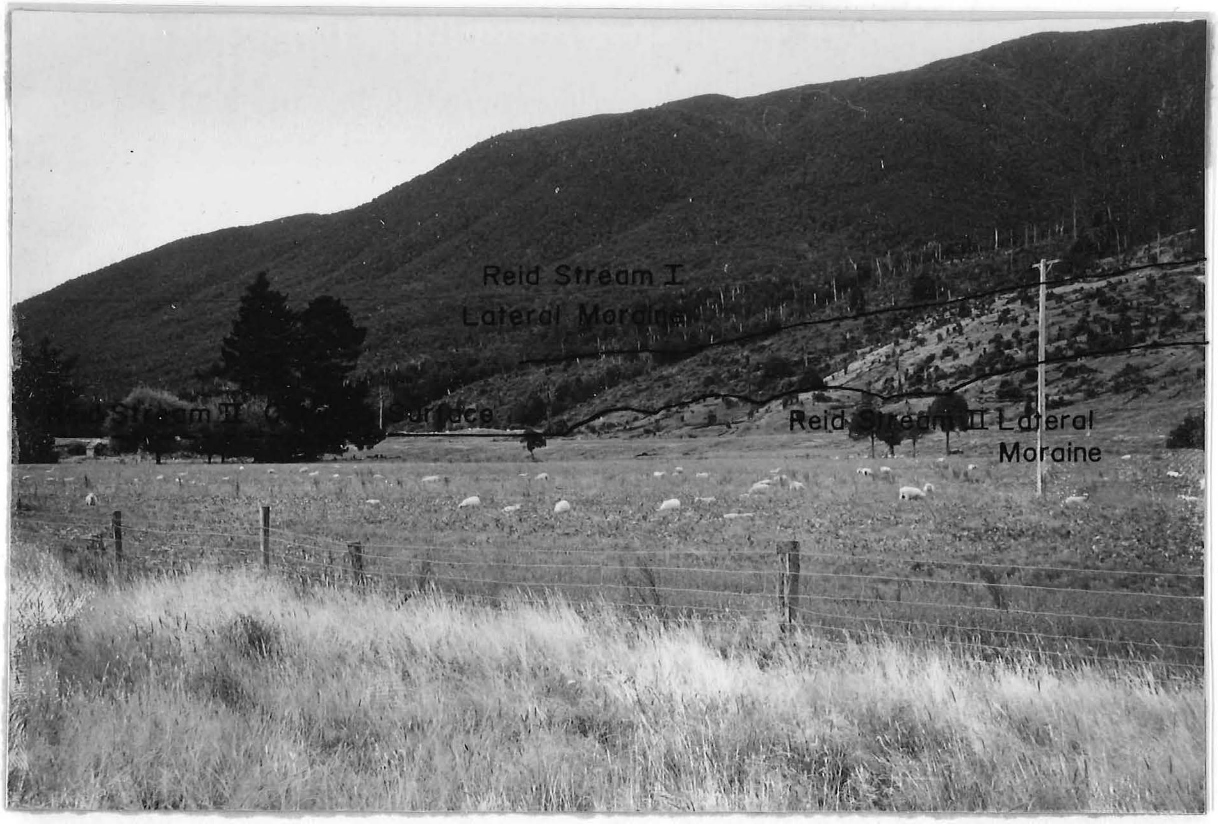

Fig. 20. Reid Stream I lateral moraine, Reid Stream II lateral moraine and outwash surface.

The lateral moraine merges into several mounds which rise 10 m above the level of the outwash surface. These may possibly be remnants of an end moraine.

1 km northwest of Springs Junction is a small ridge 1 km long and 300 m wide which rises 32 m above the river. Trig 4621 (grid ref. S46/609034) is situated on this ridge which is interpreted as a moraine ridge of the Reid Stream II advance. (Fig. 4). This probably marks the western limit of ice in the Middle Maruia Valley during the Reid Stream II advance.

Between Springs Junction and the Maruia River is a mostly bushclad hummocky area. It rises nearly 20 m above the river, but is more than 50 m below the level of the Reid Stream I ground moraine. (Figs. 4, 7). This area is also interpreted as ground moraine. Similar areas can be seen near the Sluice Box. (Fig. 4). At grid ref. S46/623308 the following section shows beneath the ground moraine surface: (Fig. 21).

5 m Non-bedded angular gravel up to 30 cm across. Interpreted as subglacial till.

Fig. 21. Reid Stream II subglacial till exposed near Springs Junction.

The Reid Stream II outwash surface is discontinuously preserved on both sides of the Middle Maruia valley and can be traced down valley as far as the Creighton I moraine loop. (Fig. 8). As it is traced downvalley the outwash surface increases in height above the river, and becomes slightly more separated from the Reid Stream I outwash surface. Near Reid Stream the two outwash surfaces are 10 m apart, the Reid Stream II surface being 13 m above the river. At Station Creek it is 20 m above the river, and just upstream of the Creighton I moraine loop it is 17 m below the Reid Stream I surface, and 26 m above the river.

The outwash surface can be traced further upvalley on the western valley side than on the eastern side. From opposite Reid Stream upvalley for 4·5 km a narrow remnant of the outwash surface can be seen. (Fig. 4). It is below the level of the Reid Stream I lateral moraines, up to 500 m wide and 12 m above the river. It extends 2.5 km further upvalley than the Reid Stream II outwash surface on the eastern valley side, and can be traced almost to the moraine ridge at Trig 4621. This configuration of lateral moraines and outwash surface remnants on either side of the valley would suggest that the glacier terminus, during the Reid Stream II advance , extended from Trig 4621 in a north westerly direction across to the lowest point reached by the lateral moraine on the eastern valley side. (Fig. 6).

Reid Stream II outwash gravels are well exposed in the Middle Maruia Valley. Several descriptions of these

gravels have already been given. (p.50 and 52).
Both these exposures were downvalley from Ure's Hill. The outwash gravels in this part of the valley are usually less than 1.5 m thick. The thickest exposures seen were less than 3 m thick. However upstream from Ure's Hill the Reid Stream II outwash deposits are considerably thicker. At grid ref. S46/640075 the following sequence appears beneath the outwash surface: (Fig. 22).

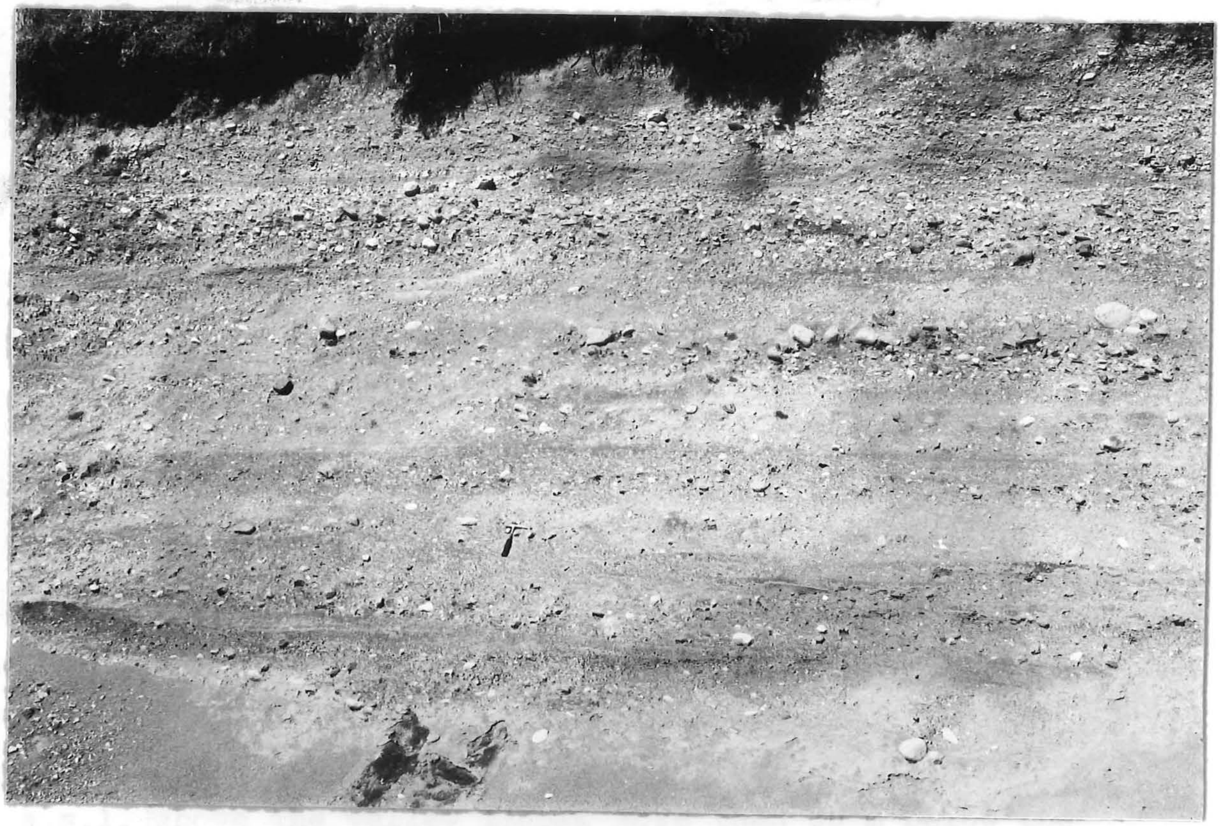

Fig. 22. Reid Stream II outwash gravels 0.5 km upvalley from Reid Stream.

9 m Bedded, subrounded grey gravels up to 20 cm across in coarse sand matrix. Interpreted as Reid Stream I outwash gravels.

Across the valley at grid ref. S46/623080 a similar sequence of gravels could be seen beneath the outwash surface. Here 12 m of fluviatile gravels were exposed. Clearly more gravels were deposited close to the glacier terminus. It appears that the Reid Stream II outwash gravels were deposited on a surface cut nearly 20 m below the Reid Stream I outwash surface. Near the glacier terminus the gravels were up to 12 m thick, however they thin rapidly down valley to be generally no more than 2 m thick. Thus the Reid Stream II outwash deposits can be seen to be wedge shaped in cross profile. This would account for the downvalley divergence of the two Reid Stream advance outwash surfaces.

Summary of the Reid Stream II Advance

This was the last advance of the Maruia glacier to extend ice into the Middle Maruia Valley. 20 m of downcutting had occurred in the interval between the two Reid Stream advances. During the advance only a minor amount of aggradation occurred. At its maximum during the Reid Stream II advance the glacier was only 0.5 km shorter than during the previous advance. However in the Middle Maruia Valley ice only reached a level of about 460 m a.s.l. [above the valley floor], more than 30 m below the ice level of the previous advance. The glacier was split into two streams by Marble Hill. The southern ice stream was probably quite small, as ice does not appear to have extended as far down the western valley side as it did down the eastern side. The Reid Stream II advance is believed to have occurred shortly after the Reid Stream I advance, and was small and short lived.

(3) The Rahu and Black Stream Flats

The history of the depression between the Upper Grey and Middle Maruia Valleys during the Creighton Advances has been discussed above (p.42). During the Reid Stream advances ice probably only extended into the northern and southern fringes of this area.

It is believed that during the Reid Stream Advances a glacier occupied the Rahu Valley. Till is exposed in road cuttings through the Rahu Saddle, and Suggate (1965 Fig. 17) maps a glacier extending down the Rahu Valley to within 3 km of the depression during this time. The Rahu Flats form a continuous surface with the Reid Stream II outwash surface. Thus they are interpreted as an outwash surface deposited by the Rahu River marginal to the Maruia glacier during the Reid Stream II advance. A terrace 2 m high can be traced down the Flats to the main terrace edge just south of Trig. 4621. It is associated with a former channel of the Rahu River which passed to the south of the moraine ridge. The present course is to the north of the ridge. The old course was probably only occupied for a short period after the Reid Stream II advance, as the main terrace edge which cuts across the channel is believed to have been formed by downcutting of the Maruia River shortly after the Reid Stream II advance.

The Black Stream flats are very poorly drained. Large swamps and several ponds can be seen. Overall these flats slope down towards the Maruia Valley. However many poorly defined slope facets exist. Black Stream occupies the lowest region of the flats.

At the southern end of the Flats several small ridges and hummocks can be seen. These are interpreted as remnants of Creighton Advance ground moraine (Fig. 4). At the northern end of the region several low ridges can be seen skirting the terrace edge west of Trig E. (grid ref. S46/617999). These may be remnants of lateral moraines from the Reid Stream II advance as they are at a similar height to the moraine ridge at Trig 4621.

The Flats are at the same height as the Rahu Flats so they have been mapped as a Reid Stream II feature. They were probably formed during the Reid Stream II advances by the reworking of the Creighton and Reid Stream I advance ground moraine deposits by Black Stream and its tributaries while the Maruia glacier blocked the stream's normal outlet. At grid ref. S46/617003 the following section shows beneath the surface of the Black Stream Flats. (Fig. 23).

0.7 m	Soil
1 m	Bedded subrounded gravels up to 10 cm across. Interpreted as reworked subglacial till.
1.5 m	Non-bedded angular gravels up to 50 cm across. Interpreted as subglacial till.

Fig. 23. Reworked subglacial till exposed in Hunter's Road.

The upper gravel layers are believed to represent subglacial till that has been reworked by local streams. The terrace edge in which this sequence is exposed is believed to have been cut shortly after the Reid Stream II advance by downcutting of the Maruia River. Thus the reworking of the till must have been completed soon after the glacier began to retreat from its Reid Stream II position.

0.5 km south west of Springs Junction Black Stream flows through a small gorge cut in the ridge which separates the Rahu and Black Stream Flats. The stream was probably forced to cut this gorge during the Reid Stream advances.

Two streams flow onto the Black Stream Flats from the eastern flank of the depression. Both have built up fans on top of the Flats (Fig. 4). The northern is the largest and is overlain by a hummocky surface 2 m above the level of the fan. This is interpreted as a landslide. The material was exposed in a freshly leveled field at grid ref.S 46/ 614989. It consisted almost entirely of very angular chips of greenschist up to 10 cm across. The landslide was probably triggered by movement along the Alpine Fault which runs along the eastern margin of the depression, and the debris may well have been derived from the Alpine Fault crush zone.

V. THE REID STREAM-SPRINGS INTERVAL

After the Reid Stream II advance the glacier receded into the Upper Maruia Valley. The Large areas of ground moraine left in front of the receding glacier were substantially eroded before the next advance. The Sluice Box was probably blocked for a time by ground moraine. This forced the Maruia River to flow under the southern flank of Marble Hill. The Black Stream and Rahu Flats are 13 m above the next youngest outwash surface, thus at least 13 m of downcutting occurred in this area between the Reid Stream II and Springs Advances. North of Marble Hill where the Maruia River presently flows, a similar amount of downcutting occurred before the Springs advance. This may have been accomplished solely by the Alfred River flowing through the Sluice Box. Alternatively the Maruia River may have abandoned its southern course around Marble Hill and joined the Alfred River to flow through the Sluice Box.

In the Middle Maruia Valley the Reid Stream II outwash surface is at least 12 m above the Springs surface. Thus the Maruia River had lowered itself at least 12 m below the Reid Stream II outwash surface before the Springs Advance.

VI. THE SPRINGS ADVANCE

This advance is named from the Maruia Springs which are close to the postulated terminal position of the glacier during this advance.

No terminal or lateral moraines of this advance have been preserved. However an aggradation surface indicating a period of abundant stream load can be traced upstream 5.5 km from the Sluice Box, and is attributed to a minor advance which probably reached as far as Maruia Springs. The outwash surface can be traced downvalley from the Sluice Box almost to Reid Stream. From here north to the Creighton I moraine loop a low terrace level is discontinuously preserved. This is not considered to be an aggradation surface. An outwash surface over 30 km associated with such a small advance is unlikely. This surface probably marks the general river level during the Springs Advance. However no aggradation occurred on it during the advance. It was formed by post-Springs Advance downcutting.

At grid ref. S46/667994 the following sequence shows beneath the Springs outwash surface: (Fig. 24).

5 m Poorly bedded subrounded gravels up to 30 cm across. Interpreted as proximal outwash.

3 m Poorly bedded subrounded gravels up to 10 cm across.

Fig. 24. Springs Advance outwash gravels exposed near the Calf Paddock.

The sequence records a change from a relatively low energy depositional environment to the higher energy environment represented by the coarse outwash gravels. Obviously vigorous aggradation by the Maruia River was in progress while the upper gravels were deposited. This aggradation is believed to have been caused by the Springs Advance. Near Williscroft's Bridge a very similar sequence of fine gravels grading upwards into coarse gravels can be seen beneath this low terrace. (grid ref. S46/636035). Thus this surface is also believed to be part of the Springs Advance outwash surface.

The outwash surface extended around the southern flank of Marble Hill, as well as through the Sluice Box into the Middle Maruia Valley. The river flowed to the south around Marble Hill for a short time after the Springs Advance. Extensive areas of abandoned river channels and small degradational terraces can be seen around Springs Junction. They are up to 3 m below the remnants of the Springs outwash surface. For the bulk of the time since the Springs advance the Maruia River has flowed through the Sluice Box. The five degradational terraces which can be seen at the Calf Paddock (grid ref. S46/653000) have been formed since this time. These terraces probably mark successive stages of the downcutting of the Maruia River in the Sluice Box.

Springs Advance Summary

The Springs Advance has been separated from the Reid Stream advances because it was very much smaller. At its maximum the glacier was at least 13 km shorter than during the Reid Stream Advances. Only a small outwash surface was formed and the advance was probably even more short lived than the Reid Stream II advance.

In the short interval prior to this advance at least 12 m of downcutting by the Maruia River had occurred. The outwash surface built up during the advance is believed to have extended as far as Reid Stream. A degradational terrace was formed in the Middle Maruia Valley north from Reid Stream subsequent to this advance.

VII. THE LEWIS PASS MORAINES

A group of moraine ridges can be seen at the Lewis Pass. A road cutting through part of a moraine ridge at grid ref. S46/809965 shows:

13 m Poorly bedded angular grey gravels up to 30 cm in a coarse sand matrix. Interpreted as till.

These moraines appear to have been deposited by the Maruia glacier. However they cannot be correlated with any particular advance in the Middle Maruia Valley. Suggate (1965) correlates them with the Reid Stream Advances, and Clayton (1968) has used them as type moraines for the youngest Otiran advance in the Waiau valleys. (See below).

VIII. THE GLACIAL CHRONOLOGY OF THE MIDDLE MARUIA VALLEY

The glacial deposits in the Middle Maruia Valley record the fluctuations of the Maruia glacier during and since the Otira Glaciation.

A chronology of the Otira Glaciation in the Middle Maruia Valley can be erected. It is based upon the extent of the geomorphic changes that occurred in the valley during and between the various advances. These changes have been described above.

Complete Disappearance of Maruia Glacier	POST-GLACIAL
Springs Advance	
Brief Recession	
Reid Stream II Advance	OTIRA GLACIAL
Brief Recession	
Reid Stream I Advance	
Interstadial Interval	
Creighton III Advance	
Brief Recession	
Creighton II Advance	
Brief Recession	
Creighton I Advance	

The correlation of this sequence with other Otiran Glacial sequences in the South Island will be discussed below.

CHAPTER IV.

CORRELATION

I. INTRODUCTION

Once a glacial sequence has been established in a valley, it is interesting, instructive and indeed necessary to compare it to other sequences, and if possible to a Standard Glacial Sequence for a region. Such correlations would be very simple if they could be based on accurate absolute ages. The most common way in which such ages are obtained is by the radiocarbon dating technique. This is capable of giving a reasonably accurate age on organic material up to 40,000 yrs old. This method is therefore applicable only to the period encompassing the Otira Glacial, and Aranuian Post glacial stages. The number of radiometric ages which date Otiran glacial events is increasing. However there are still too few of these for wide correlations to be based thereon. The methods of correlation between glacial sequences remains essentially the same as that described by Suggate (1965 p.9).

Deposits relating to the last glaciation are abundantly preserved in many alpine valleys. Thus a detailed chronology of the advances and retreats of the various glaciers can usually be worked out. These relative chronologies of Otiran glacial events will be used as a basis for the following correlations. While it is highly unlikely that all glaciers were advancing and retreating simultaneously, the various stadials and interstadials that can be recognised in each valley were probably broadly contemporaneous.

Suggate (1965) described the glacial sequences of the northern half of the South Island in three groups; North Canterbury, Nelson-Marlborough, and North Westland sequences. The boundaries of these three regions converge on a point at the head of One Mile Creek which joins the Maruia River 17 km west of Maruia Springs. The Maruia Valley lies at the southern extremity of the Nelson-Marlborough Region, and adjacent to both the North Canterbury and North Westland regions. Thus the Maruia glacial sequence is potentially an important link between the sequences in all three regions.

Initially the Otira glacial sequence in the Middle Maruia Valley will be correlated with other established sequences in the Nelson-Marlborough Region. The Maruia sequence will also be correlated with North Canterbury sequences. Finally its relationship to the North Westland sequence, on which the N.Z. Otiran Glacial chronology is based will be discussed.

II. CORRELATION OF THE SPRINGS ADVANCE

This advance was probably an early Postglacial event. Similar advances have been recorded in other areas. Thus it is tentatively correlated with the Brich Hill Advances in the Pukaki area. (Speight 1963, McGregor, 1967), the Waiho Loop of the Franz Josef Glacier (Wardle 1973, Sara 1974) and the Lake Stream advance and its correlatives in the Rakaia Valley (Burrows and Russell, 1975).

As the deposits of postglacial advances have not been described extensively in the literature, no firm conclusions concerning the Springs Advance can be made. It is not considered to be a major advance of the Maruia glacier. The last major ice advances that occurred in the Maruia Valley are believed to have been the Reid Stream Advances.

III. CORRELATION WITH NELSON-MARLBOROUGH SEQUENCES

Apart from Suggate's (1965) reconnaisance survey of the glacial sequences in this area only two detailed studies have been made. Adamson (1964) mapped the glacial sequences in the Howard, Upper Buller, and Motupiko valleys, and Nathan and Moar (1973) have mapped the Late Quaternary terraces in the lower Inangahua Valley.

(1) Correlation of the Maruia and Inangahua Glacial Sequences:

No moraines are preserved in the Inangahua Valley (Suggate 1965), but the prominent terraces in the Lower valley are believed to be remnants of outwash surfaces (Suggate 1965, Nathan & Moar 1973). Although Suggate (1965 p.40) suggested that there may be two surfaces of Otiran Glacial age in the Lower Inangahua Valley, Nathan and Moar only recognised one. This was dated at 20,300 yrs B.P. No correlation of the Maruia and Inangahua sequences appears to be possible. The 20,300 yrs B.P. date for the lowest outwash surface is older than that for the Reid Stream I advance. Thus the outwash surface is probably a correlative of one of the Creighton advances.

(2) Correlation of the Maruia & Rotoiti Glacial Sequences:

The glacial sequence in the Lake Rotoiti area was described in some detail by Suggate (1965). For the Otira Glaciation two main advances were recognised, the later one being a double event. Adamson's (1964) more detailed study emphasised the displacement of the glacial deposits by the Alpine-Wairau fault system. Again two main Otiran advances were recognised, the Black Valley and Rotoiti advances. However both were believed to have been double events. Neither writer has erected any form of chronology of the Otiran Glacial stage in the Rotoiti Area. The moraines are all closely spaced, less than 2 km separates the Black Valley from the Rotoiti II moraines. (Adamson 1964 Map II). The Black Valley I advance resulted in the formation of an extensive outwash surface, while the outwash surfaces of the subsequent advances have all been reduced to very small isolated remnants. It would thus appear that the establishment of a relative Otiran Glacial chronology in the Rotoiti area is almost impossible. The correlation of the Rotoiti and Maruia sequences can only be based on the dubious method of equating the youngest main advances in each valley and counting back from that point. The correlation of the Rotoiti and Reid Stream advances appears reasonable. Only one Rotoiti outwash surface has been recognised, whereas two Reid Stream outwash surfaces have been mapped in the Maruia Valley. However in both valleys the youngest main advance phase recorded consisted of a larger advance followed by a small retreat, then a second much smaller advance before the final retreat. The Black Valley advances probably correlate with the Creighton advances. No more accurate correlation than this is possible. The existence of three Creighton advances in the Maruia Valley in contrast to only two Black Valley advances in the Rotoiti area does not mean that an advance is missing from the Rotoiti sequence. Rather this indicates that the behaviour of the Travers and Maruia glaciers during the early Otiran glacial was rather different. The correlation of the Black Valley and Creighton advances as representatives of an early Otira stadial is probably reasonable. However during that stadial the two glaciers responded differently to the climatic conditions.

IV. CORRELATION WITH NORTH CANTERBURY SEQUENCES

Glacial sequences in this region have been described for the Rakaia (Soons 1963, Soons and Gullentops 1973) Waimakariri (Gage 1958), Hurunui (Powers 1962), and Waiau (Clayton 1968) valleys. The correlation of the Waimakariri and Waiau glacial sequences with the Maruia sequence will be discussed. The Waimakariri sequence because it is a standard work in this field, and is used for trans-alpine correlations (e.g. Suggate 1965) and the Waiau sequence because it is adjacent to the Maruia Valley.

(1) Correlation of the Maruia and Waimakariri Glacial Sequences:

The glacial sequence in the Waimakariri Valley has been described by Gage (1958), and Moar and Gage (1973). Quite a reasonable correlation with the Maruia sequence appears to be possible. The Poulter advances may be correlated with the Reid Stream advances. Both were the youngest main advances in each valley and both were double events separated by a brief recession. Gage (1958 p.126) postulates an interstadial between the Poulter and the next oldest Blackwater advances. This correlates well with the interstadial interval separating the Reid Stream and Creighton advances in the Maruia Valley. The Blackwater and Creighton advances cannot be precisely correlated as there were two Blackwater advances and three Creighton advances. However Gage (1958 p.46 and Fig. 15) has mapped a group of moraine ridges and outwash channels marking fluctuations and minor readvances of the Waimakariri glacier during its retreat from the Blackwater II maximum. Carryer (1967) reports a personal communication from Gage that a third Blackwater Advance is now recognised. This further improves the correlation of the Creighton and Blackwater advances. It is likely that the Blackwater and Creighton advances are representatives of the same stadial. These correlations appear to be very reasonable. However the status of the Otira Glaciation in the Waimakariri is uncertain. Initially Gage (1958) included the Poulter, Blackwater, Otarama, and Woodstock advances in the Otiran Glacial. However this correlation was revised (Gage 1961) removing the Woodstock advance and giving it full glacial status on its own. Suggate (1965) proposed a new glacial stage, the Waimean, which was placed before the Otiran glacial. The Otarama was left in the Otiran by Suggate, but this necessitated a significant alteration of the trans alpine correlations proposed by Gage and Suggate (1958).

However if these trans-alpine correlations are retained, as Gage (1966), Moar and Gage (1973) have suggested they should be, then the Waimea Glaciation could be correlated with the Otarama advance. This correlation is preferred. Thus the Otira Glaciation in the Waimakariri Valley is represented by the Poulter and Blackwater advances.

In the light of these adjustments to Suggate's (1965) trans-alpine correlations, the Otira glacial sequences in the Maruia and Waimakariri Valleys can be seen to be quite similar. The earlier Otiran advances were multiple, three Creighton advances being recorded in the Maruia Valley, and at least two Blackwater advances in the Waimakariri Valley. After an interstadial interval a closely spaced double advance occurred in both valleys. These were the Reid Stream and Poulter advances.

(2) Correlation of the Maruia and Waiau Glacial Sequences:

During the Otira Glaciation two tongues of Maruia ice extended across the Main Divide, at the Ada and Lewis Passes to flow into the Waiau watershed. This might have made the correlation of the Waiau and Maruia glacial sequences much easier. However the features left by these tongues of Maruia ice were small, and they were isolated from both the Maruia and Waiau sequences. So the correlation of these two sequences remains subjective.

The moraine ridges at the Lewis Pass (p.69) are the type moraines for Clayton's (1968) Lewis advance, the youngest main ice advance in the Waiau Valley. Although it is not described as a double event, this may reasonably be inferred from Clayton (1968 Fig. 2, and p. 764). In the

Waiau River and its tributaries, including the Lewis River, higher and lower Lewis advance outwash surfaces are shown, thus the Lewis advance was probably a double event. Thus the correlation of the Lewis and Reid Stream advances, as suggested by Suggate (1965, p.39, Fig. 17) appears reasonable.

Unfortunately, Clayton (1968) does not give any indication of the magnitude of time between the various advances in the Waiau Valley. However an examination of some of the information given by Clayton (1968) reveals some useful facts. The Glynnwye Advances immediately precede the Lewis Advances, the moraines being more than 20 km downvalley from the nearest Lewis moraines (Clayton 1968, Fig. 5). The Glynnwye outwash surfaces are more than 60 m above the Lewis outwash surfaces. Thus a large retreat of the glacier, and substantial downcutting occurred between the Glynnwye and Lewis advances. Clearly a long time interval must have separated the two advances. This invites correlation with the Reid Stream-Creighton interstadial in the Maruia Valley.

The Glynnwye advances, being the next oldest in the Waiau Valley probably correlate with the Creighton advances. Clayton (1968) distinguished seven separate outwash aggradation surfaces relating to the Glynnwye advance. 3 recessional moraines were also identified. The highest outwash surfaces are over 150 m above the present river level. Clearly the Glynnwye advances were a major glacial event. The correlation of these advances with the Creighton advances appears to be quite reasonable. However Clayton (1968) includes two further advances in the Otiran Glaciation in the Waiau Valley. These are the Glenhope and Leslie Hills advances which are believed to be slightly older than the Glynnwye advances. The Leslie Hills advance was recognised on the basis of "a few scattered terrace remnants on the Culverden Plains" (Clayton, 1968 p. 761). The Glenhope advance was more clearly represented by moraines and outwash surfaces, the latter only 10 m below the Leslie Hills surface. The Leslie Hills surface was probably formed during an early phase of the Glenhope advance. There appears to be insufficient evidence to give it the status of a separate advance. The Glenhope advance was correlated with the Blackwater I advance in the Waimakariri Valley. However it was also noted that "the Glenhope advance might be equivalent to the Otarama advances in the Waimakariri Valley" (Clayton, 1968, p.765). If this correlation is maintained, and also the trans-alpine correlations of Gage and Suggate (1958), then the Glenhope advance is probably of Waimean Glacial age. The ramifications of this correlation are interesting. In the Waiau Valley the Horseshoe Glaciation thus becomes a correlative of the Waimungan Glaciation, and the Kakapo a correlative of the Porika Glaciation. This latter correlation is supported by the similarity of the type and distribution of the Kakapo deposits (Clayton 1968, p.757) and Porika deposits in the Lake Rotoiti area. (Suggate 1965, p.34).

The above revision to Clayton's glacial chronology for the Waiau Valley may seem somewhat drastic. However this does not appear to create any anomalies. The initial change concerning the recorrelation of the Glenhope advance was suggested by Clayton as an apparently perfectly satisfactory alternative.

Thus the Waiau and Maruia glacial sequences are considered to show a fair degree of similarity. A major multiple advance in each valley, the Glynnwye and Creighton advances, was followed by a period of extensive rive erosion and substantial glacier retreat before a much smaller double advance.

V. CORRELATION WITH THE NORTH WESTLAND AND NEW ZEALAND GLACIAL SEQUENCE

Suggate (1965) studied in detail the glacial sequence in the Grey, Taramakau, and Hokitika valleys. For the sake of convenience this area will be referred to below as the Kumara area, and the glacial sequence proposed, as the Kumara sequence. Clear relationships were established between the moraines and outwash surfaces of the glacial periods, and the marine cliffs of interglacial periods. The glacial sequence proposed was used as the basis for the New Zealand Glacial sequence. Thus the sequence in this area is very important. Each New Zealand Glacial event is defined in terms of the Kumara sequence. Thus if a glacial event in any valley is to be placed in the N.Z. Glacial sequence, it must first be correlated with the Kumara sequence.

The following N.Z. Otiran Glacial chronology was proposed by Suggate (1965), and with revised dates by Suggate and Moar (1970).

Kumara III_2 Advance	C.14,500 - C.14,000
Minor Interval	C.16,000 - C.14,500
Kumara III_1 Advance	C.17,000 - C.16,000
Minor Interval	C.18,000 - C.17,000
Kumara II_2 Advance	C.22,300 - C.18,000
Major Interval	C 30,300 - C.22,300
Kumara II_1 Advance	prior to 30,300?

This sequence does not correlate well with the Maruia sequence. (p.70). Initially it might appear that the two Kumara III advances could be correlated with the Reid Stream advances as suggested by Suggate (1965 p.39). Both were the youngest main advances in each valleys and both were double events. However the climax of the Reid Stream I advance has been dated as younger than 14,800 yrs. (p.55). On the basis of the dates given by Suggate this would make the Reid Stream I advance a correlative of the Kumara III_2 advance, which seems unlikely.

An examination of the dates relevant to the Kumara III_1 advance cited by Suggate (1965) sheds some light on this matter. Three dates from the list given by Suggate (1965 p.84) are related to the Kumara III_1 advance. No further dates have so far been published. None of the three dates are from the Grey-Taramakau area. Thus the accuracy of the dating of the Kumara III_1 advance depends firstly upon the interpretation of the dated horizon within each local glacial sequence, and secondly upon the correlation of each of these local sequences with the Kumara sequence.

The earliest date for the Kumara III_1 advance is that of 16,600 yrs B.P. obtained from the Upper Buller

Valley. (Suggate 1965, p.35, Adamson 1964, p.208). The locality was over 15 km from the nearest Otiran moraines, and could not be related to any of the outwash surfaces in the valley. The dated horizon was interpreted by Suggate (1965) as representing lake deposition shortly prior to the Rotoiti I (Kumara III_1) advance. However Adamson (1964) suggested that the date marked the beginning of the Black Valley II (Kumara II_2) retreat. Clearly this date is in a stratigraphically poorly defined horizon that is open to a variety of interpretations.

The second relevant date is that of 15,100 yrs B.P. obtained by McKellar (1960) in the Clutha Valley, Central Otago. The dated material, a peat, was taken from the base of an abandoned river channel cut 20 m below the level of the Hawea moraine. (McKellar 1960 p.443). Thus a judgement of the actual date of the formation of the moraine depends upon how quickly the 20 m of downcutting occurred, some being through solid rock (McKellar 1960), and how soon after the channel was abandoned the peat formation began. While Suggate (1965, p.84) suggests that these events happened rapidly, McKellar (1960) believes that they took a much longer time. It was suggested that the Hawea advance was older than the Kumara III advances. Suggate (1965 p.74) rejects this suggestion on the grounds that the youngest main advance recorded in all glaciated valley in the South Island must have occurred more or less simultaneously. Therefore Suggate correlates the Hawea advance with the Kumara III advances. If this is so, then the Hawea advance is the only Late Otiran advance yet described that was not recognisably a multiple event. Quite apart from the different interpretations that can be placed on the significance of this date, the correlation of two glacial sequences over 200 km apart cannot be too secure. It is suggested that the date on the Hawea peat should not be applied to the N.Z. Glacial sequence until more is known about the effects of the Late Pleistocene Glaciations in the south of the South Island.

The third date relevant to the Kumara III_1 advance is that of 14,800 yrs B.P. obtained from a moss peat below the Reid Stream I outwash gravels in the Maruia Valley. The interpretation of this date has been discussed above (p.55). The peat formation is believed to pre-date the maximum of the Reid Stream I advance.

Of the three dates given by Suggate (1965) that are relevant to the dating of the Kumara III_1 advance, the validity of the older two is open to serious question as to their relevance to the N.Z. Glacial sequence. The other date, in the Maruia Valley, is believed to have been incorrectly defined within the Maruia glacial sequence.

If Suggate's (1965) correlation of the Reid Stream and Kumara III advances is retained, then in the light of the above considerations, the discrepancy over the dating of the Kumara III_1 and Reid Stream I advances can be resolved. It has been shown that the Upper Buller Valley date can be variously interpreted, and that the Hawea date should not yet be firmly applied to the N.Z. Glacial sequence. Thus the only date that gives any indication as to the timing of a correlative of the Kumara III_1 advance is that in the Maruia Valley. Therefore the timing of the Kumara III_1 advance and its correlations at C.17,000 - C.16,000 yrs

B.P. (Suggate and Moar 1970) should be revised to C.15,000 - C.14,000 yrs B.P.

This date for the Kumara III_1 advance leaves a gap of 3,000 yrs between the Kumara II_2 and the Kumara III_1. This would correlate well with the Reid Stream - Creighton interstadial in the Maruia Valley, and the long time interval suggested between the Glynnwye and Lewis advances in the Waiau Valley. This revised date also fits the Waimakariri sequence. Gage (1958) postulated a long time period between the Poulter and Blackwater advances. However after Suggate and Moar's (1970) revision of the timing of Late Otira Glaciation the gap between the Blackwater and Poulter advances was reduced to 1,000 yrs (Gage 1971). This was an unacceptable figure to Gage as it necessitated rates of downcutting in Broken River of 30 cm every four or five years, half of this downcutting being in resistant pre-Pleistocene strata. (Gage, 1971). A 3,000 yr gap between these two advances would reduce the rate of downcutting to 30 cm every twelve - fifteen years.

There seems to be ample support for a long time interval between the correlatives of the Kumara II_2 and Kumara III_1 advances. However no such interval is proposed by Suggate (1965). Rather, an interstadial interval is proposed for the period between the two Kumara II advances. Suggate (1965, p.51) suggested that because "two distinct main moraine ridges and two separate outwash aggradational surfaces" could be recognised an interstadial interval between the two Kumara II advances was indicated. However the two moraine ridges are very close together and can only be identified from the two lobes of the Taramakau glacier in the Arnold and Taramakau valleys. (Suggate 1965, fig. 22). It is only in these two valleys that two outwash surfaces can be recognised. The vertical separation of these surfaces is only 20 m and the younger is much less extensive than the older, (Suggate, 1965, Fig. 23). The vertical separation, and extent of the various deposits relating to the Kumara II advances suggests that there was no great time interval between them. No further direct evidence is available to support the existence of this interstadial. Moar and Suggate (1973) describe the polynology of a peat deposit which was considered to span the last 30,000 yrs. The sequence of vegetation changes is considered to represent a general climatic cooling to glacial conditions about 25,000 yrs ago (Moar and Suggate 1973). There is no evidence to suggest which of the Kumara II advances is represented. The polynological data from this site may well represent the final stages of the Oturi Interglacial and the onset of the Otira Glaciation.

It can be seen that the geomorphological evidence for postulating a long time interval between the Kumara II advances is not conclusive. The principle that was used by Suggate to identify this interstadial was ignored when the Waimakariri sequence was correlated with the Kumara sequence. In the Waimakariri Valley two Blackwater moraines with outwash surfaces more than 40 m apart were recognised by Gage (1958, fig. 3). However Suggate (1965 table 4) correlates both these advances with the Kumara II_2 advance. As has been noted the trans-alpine correlations of Gage and Suggate (1958) are preferable. Thus the Blackwater advances show much better correlation with the Kumara II advances.

There is more geomorphological evidence to support a long interval between the Kumara II_2 and III_1 advances. The Kumara III moraines are 2 km upvalley from the Kumara ii moraines. The outwash surface is 40 m below that of the Kumara II_2 advance (Suggate 1965 Figs. 22 & 24). Such a vertical distinction between the Kumara II and Kumara III deposits implies that an appreciable time interval had elapsed between their deposition. This would then correlate well with the Creighton-Reid Stream interstadial in the Maruia Valley. The Kumara II advances are probable correlatives of the Creighton Advances.

The Kumara sequence appears to need some revision. If the end of the Kumara II_2 advance can be dated at C.18,000 yrs B.P. (Suggate and Moar 1970) and if the Kumara III_1 advance did not begin until 15,000 yrs B.P., then a relatively long time interval can be seen to separate the two advances. This correlates well with other sequences. The existence of an interstadial between the Kumara II advances can be questioned. Thus a new chronology of the Otira Glacial sequence based on the Kumara sequence can be erected.

Kumara III_2 Advance	C.13,500 - C.13,000
Brief Recession	C.14,000 - C.13,500
Kumara III_1 Advance	C.15,000 - C.14,000
Interstadial	C.18,000 - C.15,000
Kumara II_2 Advance	C.22,300 - C.18,000
Brief Recession	C.23,500 - C.22,300
Kumara II_1 Advance	C.25,000 - C.23,500

VI. SUMMARY

The Otira Glacial sequence in the Middle Maruia Valley cannot be correlated with the Kumara sequence, or to other sequences based on the transalpine correlations of Suggate (1965). The confused nature of inter-regional correlations using Suggates (1965) scheme is shown in Table 1. However, by ignoring the correlations of Suggate (1965) reasonable correlations could be made with the Waimakariri and Waiau sequences. This entails some revision of the external correlation of these two sequences with the Kumara sequence, however it is believed that these are fully justified. The correlation of the Kumara and Maruia sequences remains difficult. In view of the fact that the Maruia sequence can be well correlated elsewhere, the criteria used for establishing the Kumara sequence were studied. It became obvious that this sequence could be revised better to fit the commonly occurring pattern of the Otira Glaciation established elsewhere. Thus the inter-regional correlations preferred by the present writer are summarised in Table 2. These correlations are believed to be fully consistent with the data presented by the various writers. It does not contain the serious anomalies of Suggate's correlations. It will be noted that a precise correlation of each advance is not attempted, rather the various stadials and interstadials are considered to be generally correlatives of each other.

TABLE I Inter-regional Correlations of Otiran Glacial Sequences based on Suggate (1965).

	MARUIA	KUMARA	WAIMAKARIRI	WAIAU
	Reid Stream II			
	Minor Interval			
14,000 yrs 14,500 yrs	Reid Stream I	Kumara III$_2$		
16,000 yrs	*Interstadial*	*Minor Interval*	Poulter	Lewis
17,000 yrs		Kumara III$_1$		
18,000 yrs		*Minor Interval*	*Interstadial*	*Interstadial*
	Creighton III		Blackwater II	Glynnwye
	Minor Interval	Kumara II$_2$	*Minor Interval*	?
23,300 yrs	Creighton II		Blackwater I	Glenhope
	Minor Interval	*Interstadial*	*Interstadial*	?
?	Creighton I	Kumara II$_1$	Otarama	Leslie Hills

TABLE 2 Preferred Inter-regional Correlations of Otiran Glacial Sequences.

	MARUIA	KUMARA	WAIMAKARIRI	WAIAU
13,000 yrs	Reid Stream	Kumara III	Poulter	Lewis
15,000 yrs	Advances	Advances	Advances	Advances
	Interstadial	*Interstadial*	*Interstadial*	*Interstadial*
18,000 yrs	Creighton	Kumara II	Blackwater	Glynnwye
25,000 yrs	Advances	Advances	Advances	Advances

REFERENCES

ADAMSON, J.K. 1964: Alpine-Wairau and Waimea Fault System in the Lake Rotoiti Area. Thesis, M.Sc., University of Canterbury 254 p.

ADAMSON, R.G. 1966: Stratigraphy and structure in the Northern Part of the area between the Glenroy and Matakitaki Rivers South Nelson N.Z. Unpublished Thesis, M.Sc., University of Canterbury, 168 p.

BLAKE, M.C., JONES, D.L., and LANDIS, C.A. 1974: Active Continental Margins, Contrasts Between California and New Zealand. pp 843-72. *in* BURK, C.A., and DRAKE, C.L. (Eds): The Geology of Continental Margins. Springer-Verlag, New York.

BOWEN, F.E. 1964: Sheet 15 Buller (1st ed.) "Geological Map of New Zealand 1:250,000". Department of Scientific and Industrial Research, Wellington, New Zealand.

——— 1967: Early Pleistocene glacial and associated deposits of the West Coast of the South Island, New Zealand. *N.Z.J.G.G. 10 (1): 164-81.*

BURROWS, C.J., and RUSSELL, J.B. 1975: Moraines of the Upper Rakaia Valley. *J. Roy Soc. N.Z. 5 (4): 463-477.*

CARRYER, S.J. 1967: The Glacial Deposits along the Northern Flank of the Mount Hutt Range. *N.Z.J.G.G. 10 (4): 1136-44.*

CLAYTON, L. 1968: Late Pleistocene Glaciations of the Waiau Valleys North Canterbury. *N.Z.G.G. 11(3): 753-67.*

COOPER, R.A. 1975: New Zealand and South-East Australia in the Early Paleozoic. *N.Z.J.G.G. 18 (1): 1-20.*

CUTTEN, H.N.C. 1976: The Rappahannock Group. Late Cenozoic sedimentation in the Alpine Fault zone in South East Nelson. Thesis, M.Sc. University of Canterbury. 142 p.

FARMER, R.I. 1967: Stratigraphy and structure of Paleozoic Rocks near Springs Junction South-West Nelson. Thesis, M.Sc. University of Canterbury. 167 p.

FLEMING, C.A. 1970: The Mesozoic of New Zealand:

Chapters in the history of the Circum-Pacific Mobile Belt. *Quarterly Journal of the Geologic Society, Vol. 125: pp 125-170.*

——— 1975: The Quaternary Record of New Zealand and Australia *in* SUGGATE, R.P., and CRESSWELL, M.M. (Eds) *Roy.Soc.N.Z., Bul. 13: 1-20.*

FYFE, H.E. 1935: The Geology of the Murchison subdivision Ed. by SUGGATE, R.P. 1968. *N.Z.G.S. Bul. No. 36* 52 p.

GAGE, M. 1958: Late Pleistocene Glaciations of the Waimakariri Valley, Canterbury, New Zealand. *N.Z.J.G.G. 1(1): 123-55.*

———1961: New Zealand Glaciations and the Duration of the Pleistocene. *Journal of Glaciology 3:940-3.*

GAGE, M. 1966: The Climate of New Zealand during cool phases of the Pleistocene. pp 83-94 *in* BLUMENSTOCK, D.I. (Ed.): "Pleistocene and Post-Pleistocene Climatic Variations in the Pacific Area." Bishop Museum, Honolulu.

———— 1971: New Zealand Glacial Chronology. (Letter to the Editor). *N.Z.J.G.G. 14 (2): 416-7.*

———— and SUGGATE, R.P. 1958: Glacial Chronology of the New Zealand Pleistocene. *Geol. Soc. Am.Bul. 69: 589-98.*

GRANT-TAYLOR, T.L.; RAFTER, T.A. 1971: New Zealand Radiocarbon Age Measurements - 6. *N.Z.J.G.G. 14 (2): 364-513.*

GRINDLEY, G.W. 1974: New Zealand pp 387-416. *in* "Mesozoic and Cainozoic Orogenies of the World." Geologic Society of London.

HENDERSON, J. 1931: The Ancient Glaciers of Nelson. *N.Z.Jnl. Sci. & Tech. Vol.XIII (3): 154-60.*

LINTON, D.L. 1949: Watershed Breaching by Ice in Scotland. *Transactions of the Institute of British Geographers Vol. 15: 1-16.*

McGREGOR, V.R. 1967: Holocene Moraines and rock glaciers in the Central Ben Ohau Range, South Canterbury, New Zealand. *Journal of Glaciology 6: 737-48.*

McKELLAR, I. C. 1960: Pleistocene Deposits of the Upper Clutha Valley, Otago, New Zealand. *N.Z.J.G.G. 3: 432-60.*

MOAR, N.T.; GAGE, M. 1973: Interglacial Deposits in Joyces Stream (S74), Waimakariri Valley, Canterbury. *N.Z.J.G.G. 16 (3): 321-31.*

————; SUGGATE, R.P. 1973: Pollen Analysis of Late Otiran and Aranuian Sediments at Blue Spur Road (S51) North Westland. *N.Z.J.G.G. 16 (3): 333-44.*

NATHAN, S.; MOAR, N.T. 1973: Age and Correlation of the Late Quaternary Terraces in the Lower Inangahua Valley, West Coast South Island. *J.Roy.Soc.N.Z. 3 (3): 409-414.*

POWERS, W.E. 1962: Terraces of the Hurunui River. *N.Z.J.G.G. 5: 114-29.*

QUECK, S.W. 1976: Metamorphism and Structure of the Cambrian-Ordovician sediments in South West Nelson District. Thesis, M.Sc., University of Canterbury, 271 p.

SARA, W.A. 1974: Glaciers of Westland National Park New Zealand Department of Scientific and Industrial Research Information Series No. 75.

SHEPPARD, D.S.; ADAMS, C.J.; BIRD, G.W. 1975: Age of Matamorphism and Uplift in Alpine Schist Belt N.Z. *Geol.Soc. Am.Bul. Vol. 86: 1147-1153.*

SOONS, J.M. 1963: The Glacial Sequence in Part of the Rakaia Valley, Canterbury, New Zealand. *N.Z.J.G.G. 6: 735-56.*

————1966: A Review of "Late Pleistocene geology of the

McKELLAR, I. C. 1960: Pleistocene Deposits of the Upper Clutha Valley, Otago, New Zealand. *N.Z.J.G.G. 3: 432-60.*

MOAR, N.T.; GAGE, M. 1973: Interglacial Deposits in Joyces Stream (S74), Waimakariri Valley, Canterbury. *N.Z.J.G.G. 16 (3): 321-31.*

————; SUGGATE, R.P. 1973: Pollen Analysis of Late Otiran and Aranuian Sediments at Blue Spur Road (S51) North Westland. *N.Z.J.G.G. 16 (3): 333-44.*

NATHAN, S.; MOAR, N.T. 1973: Age and Correlation of the Late Quaternary Terraces in the Lower Inangahua Valley, West Coast South Island. *J.Roy.Soc.N.Z. 3 (3): 409-414.*

POWERS, W.E. 1962: Terraces of the Hurunui River. *N.Z.J.G.G. 5: 114-29.*

QUECK, S.W. 1976: Metamorphism and Structure of the Cambrian-Ordovician sediments in South West Nelson District. Thesis, M.Sc., University of Canterbury, 271 p.

SARA, W.A. 1974: Glaciers of Westland National Park New Zealand Department of Scientific and Industrial Research Information Series No. 75.

SHEPPARD, D.S.; ADAMS, C.J.; BIRD, G.W. 1975: Age of Matamorphism and Uplift in Alpine Schist Belt N.Z. *Geol.Soc. Am.Bul. Vol. 86: 1147-1153.*

SOONS, J.M. 1963: The Glacial Sequence in Part of the Rakaia Valley, Canterbury, New Zealand. *N.Z.J.G.G. 6: 735-56.*

————1966: A Review of "Late Pleistocene geology of the

Northern part of the South Island New Zealand" by R.P.Suggate. *New Zealand Geographer 22: 100-2.*

————; GULLENTOPS, F.W. 1973: Glacial Advances in the Rakaia Valley, New Zealand. *N.Z.J.G.G. 16 (3): 425-38.*

SPEIGHT, J.G. 1963: Late Pleistocene Historical Geology of the Lake Pukaki Area, N.Z. *N.Z.J.G.G. 6: 160-88.*

STEWART, R.B. 1972: Mt. Mantell Highlands S.E. Nelson. Thesis, M.Sc. University of Canterbury. 81 p.

SUGGATE, R. P. 1963: The Alpine Fault. *Transactions of Royal Society N.Z. (Geology) 2: 105-29.*

————1965: Late Pleistocene Geology of the Northern Part of the South Island, New Zealand. *N.Z.G.S. Bul. 77, 91p.*

————; MOAR, N.T. 1970: Revision of the Chronology of the Late Otira Glacial. *N.Z.J.G.G. 13: 742-6.*

WARDLE, P. 1973: Variations in the Glaciers of Westland National Park and the Hooker Range, New Zealand. *New Zealand Journal of Botany 11: 349-88.*